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ELECTRIC SHIP-LIGHTING

A HANDBOOK ON THE

PRACTICAL FITTING AND RUNNING OF SHIPS' ELECTRICAL PLANT

FOR THE USE OF

SHIP OWNERS AND BUILDERS, MARINE ELECTRICIANS AND SEA-GOING ENGINEERS IN CHARGE

BY JOHN W. URQUHART, ELECTRICIAN

AUTHOR OF "ELECTRIC LIGHT," "ELECTRIC LIGHT FITTING," "DYNAMO CONSTRUCTION," ETC.

WITH NUMEROUS ILLUSTRATIONS

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PREFACE.

THE following pages contain practical details of the installation and running of Electrical Plant aboard Ship. While a considerable proportion of the whole is allotted to the treatment of such subjects as the use of electricity in ships of war, and its application to navigating purposes in the mercantile marine, the greater portion is devoted to the electric lighting of steamers.

This is a subject which has within a short recent period assumed very considerable importance. While electric lighting has at length proved itself suitable for every kind of illumination, its rapid adoption for steamships indicates its special adaptability to that purpose. The difficulties and dangers of the old system of lighting by oil lamps doubtless led in the first instances to the trial of electricity aboard ship. There were many dismal predictions of failure, none of which, happily, have been fulfilled. Electric ship-lighting is unquestionably a safe method of lighting. It adds immensely to the comfort of ocean-going passenger steamers. It assists below decks in maintaining the purity of the atmosphere—always a source of difficulty in ships carrying emigrants. It generally permits of insurances being effected at diminished

outlay. In many instances the light is cheaper than that from oil; and, finally, the sumptuous furnishings of large ocean liners owe no small part of their striking effect to the judicious use of the incandescent lamp for illumination.

In the Introduction an attempt has been made to elucidate in simple language the main characteristics of electric lighting, in so far as they may be expected to concern the mechanical sea-going engineer, who has his ordinary duties augmented by a call to take charge of the lighting arrangements. Chapters I. to IV. deal with the pre-arrangements for electric lighting necessary on the part of the ship-builder, and the class of plant generally used for sea-going purposes. Chapter V. is devoted to the handling of search and signal lights for men-of-war, and lamps for cargo purposes. Chapter VI. contains details, on a practical basis, of the fitting of ships with the distributing system; while Chapters VII., VIII., and IX. are devoted to testing, overhauling, and accessories generally, the methods used at the present time being strictly adhered to.

Finally, in Chapter X. full details will be found of the installation now in use aboard the White Star Line ship *Majestic*, under the care of Chief-electrician McKay, to whom the Author is indebted for many interesting particulars relating thereto. An illustration of this fine steamship is given as a frontispiece to the work.

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ELECTRIC SHIP-LIGHTING.

INTRODUCTION.

HINTS TO ENGINEERS IN CHARGE.

Theory of the Electric Light.—However desirable it may be to study thoroughly the fundamental facts underlying the production and application of the electrical current to lighting purposes, it is certain that a large proportion of those in whose charge the necessary plant is placed have neither the inclination nor the leisure to take up the subject with an earnest intention to master it. So it is, indeed, with reference to many other applications of electricity. The man who manipulates the instruments or machines remains, unfortunately, ignorant of the principles underlying them. So long as he is capable of "getting out of the tight places," or, in other words, overcoming the difficulties that arise in practice, he is content. We may deplore this indiffer-

ence, the more so as the effects of it fall entirely upon the class of men concerned, but it appears almost hopeless to induce the ordinary workman to enter upon a course of study, however short. This is the more noticeable in men who have entered upon the real work of life, and who are burdened by other cares.

But there are many encouraging exceptions. Young men who are but beginners are a hopeful class, and so are many others who have a natural bent for inquiry.

It is an unfortunate circumstance that the study of electricity is generally presented to the beginner in an awe-inspiring form. There is a greater or less effort to grasp the whole vast subject within the circumscribed limits of a few difficult pages of a text-book. There is seldom an effort to dissect the subject, and to impart an idea of the principles underlying one of its members at a time. When we add to this the obvious *discouragement of physical and mechanical analogies*, so prominent a feature of text-books, it is little wonder that many are discouraged at the outset. Minds trained to deal with and grasp *things* in place of abstractions dwelling chiefly in the brain, find it difficult to conceive these abstractions as governing a physical force like electricity.

We have small sympathy with the individual who bespeaks himself as a *practical* man, and who pretends to ignore what he is pleased to call "mere theory." Ignorance of the grossest sort generally dwells therein; but it is impossible to be indifferent to the natural outcroppings of the mechanical engineer's ideas of electricity when he speaks freely of electro-motive force as "pressure," and of current as "flow." After all, if it be proved that there is no

pressure, in that sense, nor yet any *flow*, of that sort, yet the idea, it must be admitted, is not so very misleading to the man of application. And such harmless analogies are, we submit, of great assistance to beginners, and frequently lead to their gaining a still deeper knowledge. The older physicists professed a horror of all such analogies, foretelling dire results if they gained a footing amongst students. But it is encouraging to see leading lights like Drs. Fleming, Thompson, Lodge, and Ayrton, not only

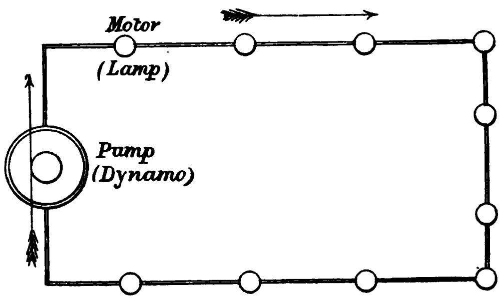


Fig. 1.—Diagram of the Hydraulic Analogy.

countenancing mechanical analogies, but inventing new and ingenious applications of them.

Hydraulic Analogy of the Electrical Current.—We offer no apology for attempting to speak to the mechanical engineer in his own language, and to present to him an idea of the electric lighting current based upon the analogy of water circulating in a pipe. It is only necessary that he should be on his guard to remember that in electricity we have no substance flowing and no pipe to contain it.

The dynamo, Fig. 1, may be regarded as a centrifugal pump. It impels an invisible force through a wire instead of a visible substance through a pipe. But the effect may be taken as the same. The dynamo impels a flow, at a certain pressure, in the conducting system. The discharge-pipe of our electrical pump is carried in a circuit to the farthest point where a lamp is required and back to the pump, being connected there to the suction opening.

If the pump and the pipes be full of water, the rotation of the former will obviously cause a circulation of the water in the pipe. A certain amount of energy will be wasted by the pump. It will be expended entirely upon the friction of the water moving in the pipe. Within the pipe, then, will be a "continuous current" of water. If a little water-motor be fixed in the circuit of the flow, it will spin around as fast as the movement of the liquid will impel it. The motor will add a certain amount to the expenditure of energy by the pump. Another and another motor may be fixed upon the water circuit, and the only effect will be to put more and more work upon the pump. The motors will work just as fast as the pump is capable of circulating the water. This is nearly the kind of effect that takes place in an arc electric-lighting installation. The engine that moves the pump is the prime motor; the pump is the dynamo; the pipe is the cable or wire, and the water-motors represent the arc-lamps. The friction or impediment experienced by the moving water has a certain analogy to the resistance offered by an electrical conductor. This resistance or friction, in the case of water, is increased as we add motor after motor to the circuit.

Such a dynamo would be called a *continuous* current dynamo. The circuit is a simple *single circuit*, and the distribution of the lamps upon it is called *series* distribution. It would as a whole be correctly termed arc lighting on the continuous current series system. This method is largely used in the lighting of docks and warehouses, and in running arc lamps aboard men-of-war. It is not used for the working of incandescent lamps.

An arc lamp consists of an arrangement for holding and controlling a pair of carbon or graphite rods, end to end. When the current passes through the rods a light appears at the point of contact. If the ends of the rods be separated a short distance, the light will become much more intense, and will appear as a flame. So long as the carbons are kept the correct distance apart, the flame, which is termed an electrical arc, remains steady. The carbons are slowly consumed. That from which the current flows burns away the faster. It is the function of the electrical device called an arc lamp to maintain the carbon rods a constant distance apart.

Analogy respecting Pressure and Flow.—It is said that the supposed water-pump must exert a certain *pressure in pounds* in order to overcome the friction of the circulating pipe and the supposed motors. At a certain pressure in pounds the pump will be enabled to cause a flow of so many gallons per minute. The same partially holds true in the case of electricity. The pressure of the pump becomes to the electrician the *electro-motive force* of the dynamo, which is measured in terms of the *volt*, a unit of electrical pressure. Hence, we say that the dynamo exerts an electro-motive force of so many volts. With the pump a

certain number of gallons of water would flow in a given time when a certain pressure is exerted on the circuit. The electrician terms the flow current, and the amount of it is measured in *ampères*, the unit of the electrical current.

The term *potential*, or potential difference, is frequently used to denote the power of a dynamo to exert electrical pressure. It is thus said to have a potential of so many volts. The analogy of friction in the pipe causing resistance to the flow of the water becomes electrical resistance, or rather *conductor resistance*, in the case of electricity. The engineer says that he loses so many pounds pressure owing to friction. The electrician has a unit for the resistance of the conductor, called an Ohm. It is thus said that there is a loss of so many volts owing to the conductor having a resistance of so many ohms. The engineer's water motors would each offer a resistance to the flow of water. Similarly the arc lamps in the case of electricity offer each so many ohms resistance.

The engineer finds that to run a water motor a certain pressure in pounds must be exerted by the pump. Similarly, to light an arc lamp a certain potential in volts must be exerted by the dynamo. If one lamp calls for a pressure of 40 volts, two would call for 80 volts, and so on. We must add to this the volts required to overcome the resistance of the conductor, which might be 10 volts more, thus the whole arrangement would absorb a "voltage" of 90. Similarly, a certain number of gallons of water per minute is required to flow through the water motors to develop their full effect, and, likewise, each arc lamp calls for 10 or more ampères of current to fully light it. But in this case, since the water in gallons is avail-

able throughout the whole circuit, and flows from the first to the second motor, and so on, the quantity required for the first suffices for all.

So with arc lamps, a current of 10 ampères being sufficient for the first lamp, it may be conceived to be sufficient for the subsequent lamps in that circuit. Reverting to our analogy, if the first water motor be stopped, the flow of water will cease, and the whole system come to a standstill, but it is conceivable that a by-pass or shunt might be provided to allow of the flow of the water past that motor in case of accidental stoppage.

If this by-pass or loop be under the control of some device whereby the stopping of the motor would shift the water flow through it, then we should have a system that would operate constantly, irrespective of faults in the motors. This is exactly what is effected in arc lamps. Each lamp is provided with a by-pass, loop, or shunt so arranged under the control of the current that any stoppage of the latter through the carbons of the lamps automatically opens the by-pass and continues the flow through the other lamps. But it is obvious that if each lamp take a pressure of 40 volts, the first one thrown out of the circuit as above would yield its 40 volts back to the circuit, and this would cause *overrunning* of the remaining lamps.

It is of course possible to insert such a resistance in the by-pass or shunt as to absorb the surplus 40 volts, but since this arrangement would yield no work in return, the volts would be totally lost. Hence, it is usual to furnish the dynamo with a device which, upon the withdrawal of a lamp from the circuit, causes the machine itself to *diminish its pressure* to the required

extent, and the 40 volts are given back by the engine having to exert less force in moving the whole system.

Friction and Power: their Analogy to Heat and Light.—Our supposed pipe would offer so much friction, and our motors would exert so much moving effect. Similarly, the wire would offer resistance and the lamps would yield light. All the friction in the case of water is no doubt dissipated as heat. All the resistance in the case of electricity is dissipated as heat. There is great resistance offered by the lamps, and the energy required to overcome it appears as heat, either in the arc or in the wires. Resistance to the electrical flow quickly makes its appearance as heat. The conductors being dry and encased, rapidly become hot, and an excess of current flowing in them rapidly raises them to fusing point. Hence, danger from *fire* is to be apprehended by reason of bad regulation of the electrical current, and in this instance our analogy to the case of a water circulation ceases. Incandescent lighting consists essentially of lamps holding conductors, kept at a *white heat* by the passage of the current through them. They are thus truly heat lights. The actual electrical light is best observed in the arc lamp, when the current is compelled to leap across a gap in the conducting system.

Personal Shock.—Our hydraulic analogy again fails in respect of the danger to the person of a high voltage from the dynamo. If a current of some 200 to 500 volts be caused to flow through the body, a shock will be experienced. The shock may pass through the body from hand to hand or from the hand to the feet, or indeed between any two parts of the system.

The human body acts the part of a conductor. Its internal resistance to the current is fairly constant, and is not great, owing to the fluids in circulation. But the resistance of the *skin* varies immensely between different persons, and also in the same person. This is due chiefly to the condition of the skin in respect of moisture. Dry skin is a bad conductor of electricity; moist skin a good conductor. Engineers at sea, owing to the liability to get the feet wet, are more liable to receive shocks than engineers ashore.

It is a good precaution to wear a pair of rubber-soled shoes while attending to circuits when high pressures are used. Engineers at sea are also more apt to receive personal shock, because most electrical work aboard ship is so wired that the body of the ship is on the circuit. Hence, any wet flooring may be inferred to be in the circuit; and while ashore it might be safe to touch any metallic part of a circuit with one hand, the same rule does not apply at sea, where a disagreeable shock might be received by merely touching the circuit with one hand. In this latter case the circuit would by inference be closed through the feet. It must not be inferred that a shock cannot be experienced from the current generally used at sea. A pressure at the dynamo of 110 volts is in common use, and although this voltage may be generally regarded as safe, yet under certain conditions of good conduction a severe shaking up may be received by passing such a current through the body.

Series Circuit not suitable to the Case of Running Incandescent Lamps.—So far we have considered only the simple case of a single circuit, in which are placed the arc lamps. This system is well adapted to the case of arc lighting, and is much used, as

before stated, in connection with shipping, and aboard men-of-war. But for incandescent lamps the series system is quite impracticable. One of the reasons for this is the high voltage or pressure required in incandescent lamps. This is seldom under 50 volts *per lamp*, and is, as a matter of fact, generally 100 volts *per lamp*. In the latter case a small batch of only 10 lamps would require, on the series system, 1000 volts of electrical pressure at the dynamo. Apart from the great danger attending the use of such a pressure aboard a ship, it is clear from what has already been said, that the breaking of one lamp would extinguish all the others upon that circuit. An automatic by-pass might indeed be used upon each lamp as in arc lighting, but the complications arising from that system would render incandescent lighting by its aid a difficult matter in practice. In speaking of high pressures, it must not be inferred that dynamos running circuits containing arc lamps of necessity yield high or dangerous pressures. It must be remembered that arc lamps, being powerful sources of light, are only used in limited number, and it is rare in ordinary work to find more than five of them upon a single circuit.

Hydraulic Analogy respecting the Parallel System for Incandescent Lighting.—Let us again take the case of a centrifugal pump forcing water in a pipe. In this instance let a pipe be attached to the suction of the pump and another pipe be attached to the delivery outlet of the pump. Let the pipes be placed parallel, and let their far ends be plugged up. Suppose now that a series of small pipes, each with a stop-valve, be connected across from one pipe to the other, after the manner of the rounds of a ladder.

Let us now assume that the pump is so arranged as to maintain a *constant pressure* upon the delivery side and a constant suction upon the suction side. No current can flow if all the stop-valves be closed. If one valve be opened a certain current will take place across that pipe, due to the constant pressure exerted by the pump. If two or three valves be opened, twice the current, or three times the current, will flow across from one pipe to the other. The total quantity or current will be equal to the current that can flow through one valve multiplied by the number of valves opened.

It will at once be seen that in this system each valve (lamp) is independent of all the others. The

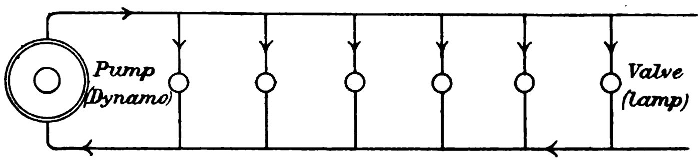


Fig. 2.—Diagram of the Hydraulic Analogy.

pump (dynamo) is so arranged, as already stated, that it maintains the pressure the same irrespective of the amount of water flowing across Fig. 2.

Still following our analogy, the greater the number of valves opened the greater the flow from one pipe to the other. The loss due to friction increases in proportion. In like manner the flow of electricity depends upon the number of lamps burning, and the size of the main cables is calculated to accommodate a flow equal to the demand when all the lamps are switched on. If water be pumped into a pipe, as we have supposed, it will be found that the pressure is

greatest at that valve nearest to the pump. It will diminish as the distance from the pump is increased, and will be weakest at the last valve of the system. The same occurs in the case of electric lighting. The lamps nearest to the dynamo will be the brightest, and the remote lamps, receiving less pressure, will burn with diminished brightness.

Here we have the same factors as before. The pump is our dynamo, the two pipes our main or leading wires, and the cross-pipes and valves the lamps. It is clear that the dynamo must be capable of maintaining the full current required when all the lamps are alight.

If, now, one-half of the lamps were to be turned out, it would appear that the resistance offered by the mains would be so diminished thereby that too much current would flow in the remaining lamps. But the practice is to make the mains so large in proportion to the work put upon them that the drop in pressure, due to all the lamps being turned on at once, shall not exceed two or three per cent. of the whole. In this way the resistance of the mains may be neglected.

In an incandescent system of lighting the 100-volt lamps are generally used. Therefore a dynamo giving a pressure of 100 volts, plus the volts that would be lost in the resistance of the wires, is used. Each lamp may require rather over half an ampère of current. The dynamo must be equal to a demand upon it for current corresponding to the number of lamps, each taking this current.

It will be particularly observed that, while on the series or arc system, already spoken of, the *pressure* or *volts* must be equal to the pressure or lamps required

by one lamp multiplied by the number of volts in use, exactly the reverse of this is true of the parallel system. Here the dynamo has only to maintain a pressure equal to that required for *one* lamp, but it must be ready to supply a *current* for one or the full number. In the former case the volts vary as the number of lamps, in the latter case the *ampères* vary as the number of lamps.

It has been said that the distant lamps are liable to be less brilliantly lighted than the near lamps. This effect is true of an extended system of lighting, but, when ample leading wires are used, it is not true in respect of short circuits, as they are used aboard a ship. In this case the variation of pressure due to all the lamps being in circuit or turned off is not appreciable, and therefore every lamp burns with equal brightness. In order to secure this result the circuit does not strictly in all cases consist of a pair of mains with dead heads and connected across as we have supposed.

When a great number of lamps are to be fed by the main, the dynamo is not connected to their ends, but midway of the number of lamps. In this latter case both the pairs of extremities are made "dead ends," or, in other words, are insulated.

Electrical "Circuit."—Our first hydraulic analogy took as its basis a pump, furnished with a circuit of piping extending from the delivery outlet to the suction side. Any work, such as motors, that was required from this circuit was supposed to be inserted therein by cutting the circle of piping, and making the circle again good *through* the motor, which would thus be said to be *placed in circuit.*

In the actual case of an hydraulic system, this

circuit need not necessarily be complete in the same sense. The water might be drawn from one source, and discharged into another. Strictly speaking, the same holds good of an electrical circuit. Although a dynamo is generally made to work through a circuit of metallic or other conductors, this is not always the case. It may "discharge" into the earth. But there must always be a corresponding earth connection to the far end of the circuit. In other words, although the leading wires are generally led from the dynamo in pairs, one of these may be dispensed with, the earth or any intervening conducting material being made to serve as the *return* wire.

Earth and Ship Return.—As a matter of fact, the wiring of ships for incandescent lighting is largely carried out on the above plan. There is only one leading wire, the *return* being made through the metal of the ship's shell. But it should be borne in mind that in every case a complete and unmistakable electrical circuit, generally through metallic conductors, must be maintained. The diagram (Fig. 3) will serve to elucidate this. In other words, while our hydraulic analogy may appear conveniently elastic in this respect, there is no such elasticity in the case of the dynamo. Telegraphy is carried on with a single wire across oceans, by means of a good "*earth*" connection at either extremity of the line, but we are not aware that electric lighting has been successfully carried on by similar simple means. To "earth" the end of a conductor is to so connect it to some metallic body having a large surface of contact with the earth, or with water, as to form a complete conductive circuit.

When a conductor is carried throughout a ship, and a connection is taken to one terminal of each lamp, the corresponding terminals on the other side of these lamps are connected to the ship's body. But as that body is immersed in the sea, the connection is essentially an *earth* connection—in other words, the lamp terminals are "earthed." But it may not

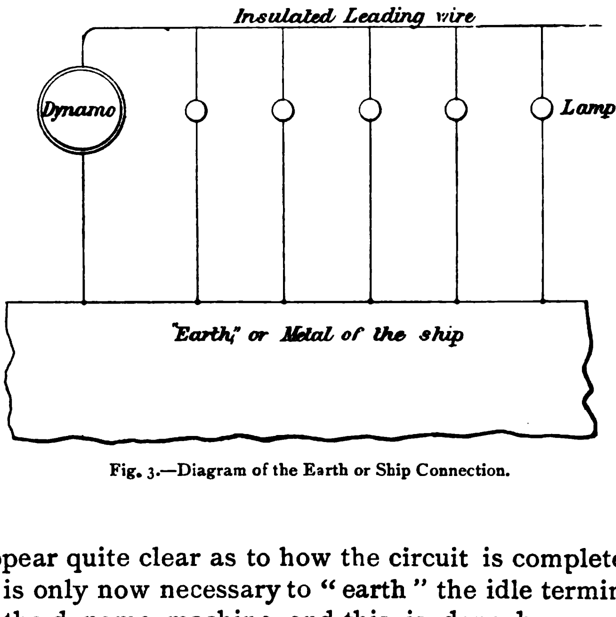


Fig. 3.—Diagram of the Earth or Ship Connection.

appear quite clear as to how the circuit is completed. It is only now necessary to "earth" the idle terminal of the dynamo machine, and this is done by merely connecting it through a piece of cable to the ship's body. In all such cases the *circuit* must be maintained. The slightest break therein introduces so enormous a resistance that all electrical effect immediately ceases. In still other words, the resistance

of metallic conductors is small; the resistance of air or non-metallic substances is very great.

Electrical Isolation—"*Insulation.*"—Most non-metallic substances present a great resistance to the passage of electricity. It is well known, however, that water is a fair conductor, and that damp substances are therefore partial conductors. But such substances as gutta-percha, pitch, wax, and so on, so largely used in insulating work, offer so great a resistance that they are looked upon as *insulators*. There is, however, no perfect isolator, and sufficiently thin coatings of the so-called "insulators" will permit the flow of electricity through them.

It is of great importance to the engineer in charge of electrical plant to understand the value and use of the so-called insulators or insulating substances. Cables and wires intended to confine the current, so that it shall not escape to "earth," and so by earth return to the dynamo, are generally sheathed in gutta-percha, and protected by other wrappings against mechanical injury. Electric lamps may have metal fittings, but care is always taken to insulate the leading wire by surrounding it with a sheath of hard rubber, bone, ivory, glass, or wood, or such insulator.

The parts of a "switch," or circuit interrupter, are generally of brass or copper, but the base upon which they are fixed and work is invariably of an insulating nature, as wood, hard rubber, or slate. Wood is a good insulator when *quite dry*, but it is apt to absorb moisture and permit an escape. Hard rubber—ebonite—vulcanite, vulcanized fibre, stone, or slate, do not absorb moisture, and are generally used for the bases of switches and lamps. But where there are

large currents of high voltage, slate is to be preferred because it is incombustible. Electric arcs are apt to be started at switches, and such accidents frequently cause fires by burning the base of the switch.

One of the most effective insulators known, if not the most powerful, is paraffin in the wax or solid state. When pure, it is quite colourless, and although it is not available for many purposes in electric lighting, owing to its low melting point, it can be made most useful. Its most important application is that of a protection against damp or moisture. Dry wood well soaked in melted paraffin may be regarded as an insulator of the first order. Insulating plugs, through which to pass cables through ships' bulkheads, are frequently made of hard wood, well paraffined. This insulator is inexpensive, and easily manipulated, but it must not be depended upon where there is a likelihood of heated conductors or fittings, or near the warm parts of lamps, nor about the fittings or wires of dynamos.

Various "Voltages" and Insulators.—When a mechanical engineer deals with pressure, he is careful to select such material and substance of pipes for its distribution as will be likely to withstand the bursting tendency. In like manner we may roughly regard the tendency of a current at high tension to be to escape from its conductor. We may regard the india-rubber sheath of an insulated wire as our pipe, and the wire itself as the empty space within. The sheath or insulator is the point of importance, and its strength *as an insulator* must be proportionate to the volts of pressure to be confined by it. Mere

mechanical strength is [illegible]. The sheath must be an effective insulator [illegible] and of limited length.

A current of very low pressure, say of a few volts only, might be effectually confined in the wire by a mere varnish of rubber or paint. But a current at high voltage may require a heavy and hard insulator to insure its safety without loss.

A cable laid along a dry wall [illegible] would be very fairly insulated without any covering, but no electrician would depend upon such [illegible] insulation. In the case of a ship where the hull of the vessel is made to do duty as the return wire, it is obvious that care must be taken to isolate the leading wire from every metallic part [illegible]. There may be a tendency to escape [illegible] part of the current, but its most powerful tendency is [illegible] *wire* [illegible]. This tendency must be [illegible] by the attendant of an electrical plant [illegible] *circuits* [illegible]. Aboard ship where damp generally prevails and where there is a "ship return," the tendency to short circuiting [illegible] is greatly magnified. The most approved methods for the locating and treatment of partial short circuits on shipboard are treated in a subsequent chapter.

Nature of the Dynamo.—Turning now to the source of electricity, it will be seen that, considering its nature, it is best spoken of after our brief examination of the [illegible] the plant. A dynamo is merely a transformer or converter of mechanical force into the force we call electricity. It has no inherent virtue in itself and is in fact a mere *special* arrangement of iron and insulated wire.

Its fundamental principles are easily understood, but their development and application have opened up a vast and interesting field of inquiry. In front of and between the extremities or poles of every magnet there is a space in which a certain attractive force for iron is exerted. It is known that this space, which is called the magnetic field, is filled with lines of magnetism, called lines of force. The lines can easily be shown to flow from one pole to the other, after the form of an arc, or a double arc, according to the shape of the poles. There is in fact a tendency to set up a magnetic *circuit*. But the resistance of the air gap is so great that the circuit may be regarded as incomplete. If, however, an armature of iron be placed across the gap touching the poles, the circuit will be completed through it, and it will become part of the magnet. If this armature be separated from the poles and be caused to revolve near to them it can be shown that in its substance electrical currents are set up. The currents cannot, however, be made available externally, chiefly because of the difficultly of collection. But if the iron armature be surrounded by a coil of insulated wire, the currents will circulate therein, and may easily be collected therefrom by a rubbing connection while the armature revolves.

The magnet is the *field magnet*, the wire-coiled iron is the *armature* the rubbing connection is the *commutator* or *collector*, and the whole forms a dynamo-electric machine. In modern dynamos the magnet is not the usual mass of hard steel, permanently magnetized. An electro-magnet, consisting of an iron core with surrounding coils of insulated wire, is used instead. It presents the advantage that in a

comparatively very small space an enormously powerful magnetic field can by these means be induced. Part of the current taken off the armature circulates in the field magnet, energising it to the required extent. Dynamos are, however, made with permanent magnets of steel, and in many cases large dynamos have their field magnets excited by the current from a separate smaller dynamo. Nor do all armatures contain iron. A mere conductor rotating in a magnetic field will have induced in it currents corresponding to its speed and the number of convolutions of the conductor. The nature of the various kinds of winding employed for regulating purposes, both upon armatures and field magnets, is touched upon in a subsequent chapter, and their attributes pointed out.

Driving.—The armature of a dynamo is caused to rotate by connection with a steam engine by one of the following methods: (1) By direct connection, the two shafts being co-axially coupled, end to end; (2) by a belt, which may be either a long belt, worked open, or a short belt, held around the pulley by means of a curbing or tightening gear, or by an endless rope running in several grooves with a jockey pulley to take up slack; (3), by peripheral friction gear, in which case the dynamo pulley is covered with leather or other partially yielding substance.

The dynamo in the latter case is usually caused to ride upon a pair of trinnions, so that contact between engine fly-wheel and dynamo pulley may be maintained by means of a spring. This latter method is chiefly used in the case of small dynamos.

These various methods, and several modifications of them, are examined in a subsequent chapter, their

application to different purposes are explained, and their merits and faults pointed out.

Incandescent Lamp.—When the carbon rods in an arc lamp touch lightly together, there occurs, upon the passage of a current, the electrical incandescence so much used in lighting. But it is still more intense in a vacuum. Any metal may be brought to a state of incandescence by a current sufficiently powerful, but no material yet tried withstands its effects so long as hard carbon in the form known as graphite. But the slender thread of carbon used in the incandescent lamp vanishes as vapour in a twinkling as soon as the air is admitted to it. When the vacuum is good within the little glass bulb, and the carbon filament of uniform section and material and sufficiently hard, it may burn under favourable circumstances as long as 5,000 hours before it breaks, but the average life of the incandescent lamp is probably not one-fifth of this.

Circumstances favourable to the long life of the incandescent lamp are as follows:—A current under such pressure that the full candle power of the lamp is developed. A current *unvarying in its voltage* (or pressure), in other words, a perfectly steady current, free from fluctuations, especially sudden changes of strength. The seldomer a lamp is turned off and relighted the better for its longevity. Lamps are easily destroyed by electrical pressure much above the volts marked upon them by the maker. When an incandescent lamp is nearly at the breaking-point it not only emits a light of extra brightness, but assumes a blue tint. This appearance immediately precedes the rupture of the filament.

Other Methods of Illuminating by Electricity.—

Apart from the direct current distributed to arc lamps upon the series system, and to incandescent lamps upon the parallel system, as already explained, the most important is the alternating current. This implies that the current is not continuous in one direction. It changes its direction hundreds of times per second. This is due to a special kind of armature used in the dynamo. The alternating current is well adapted for both arc and incandescent lamps, but it is not as safe with regard to the risk of personal shock aboardship as the continuous current. It is very little used at sea. The alternating current is admirably adapted for electric lighting in towns where the point of consumption is far distant from the dynamo. In such case it is given off by the dynamo at a very high pressure, sometimes as high as 5,000 volts. This pressure is not, however, allowed to enter the house of the consumer. High tension current may be *converted* down to low tension current by means of an inductive device known as a transformer. Such pressures as the above would be transformed twice, at the distributing station down to about 2,000 volts, and at the consumer's house down to the 100 volts or 50 volts, as the case might require for running the incandescent lamps. We cannot enter here upon a consideration of this subject, vast in itself, as it does not apply to ship lighting as now practised, but it may be mentioned that the chief object for the employment of so high a voltage as 5,000 is the great saving thereby effected in the cost of the copper conductors by this means. As may be expected, however, such conductors must be very effectively insulated to withstand so enormous a pressure.

Methods of wiring, and of running circuits, and of "feeding" them are also numerous, but none of those, with the exception of the series and parallel systems already mentioned, fall within the scope of the present work.

Electrical Current Storage and Accumulators.—In many ships the dynamo is kept constantly running, night and day. In such cases there is generally a duplicate set of plant to insure against stoppage of the lighting in case of breakdown. But there are numerous instances where only a single dynamo is used, which cannot conveniently be kept in motion at all times. In such cases the lighting is maintained by a certain amount of current previously stored in an accumulator.

The principle of the storage battery or electrical accumulator cannot be elucidated here, but the fundamental fact underlying it is that if two platinum plates be connected respectively to the two terminals of a source of electricity and plunged separately into water, a very short continuance of the current suffices to show that, upon disconnection, the plates have stored a certain amount of energy. This is shown by connecting the plates to a voltmeter. The current yielded back by the accumulator cell is opposed in direction to the charging current. In practice, platinum plates are not used. Lead perforated plates, the perforations being filled with minium and litharge, are employed in a vessel filled with acidulated water.

Electricity on Ship Board.

The application of the dynamo-electric current to

lighting purposes was speedily found to be of immense advantage to steamship owners and ocean passengers. It solved at once many difficulties, more especially in the case of passenger steamers. It very materially reduced the risk of fire from lamps; it reduced the trouble and expense of attendance; it utilised the steam of the main boilers for lighting; and it generally proved a great boon to passengers and crew alike.

Early Application of the Light.—There can be no stronger proof of these claims than the almost universal adoption of electric lighting aboard steamships within a very few years of the introduction of the incandescent system. Indeed, so great appeared the advantage that, before the glow-lamp was developed, or capable of being used in general lighting, both arc lamps and electric candles on the Joblochkoff system were freely used aboard ship. And even before either of those sources of light could be said to be perfect, the advantage of the arc light for discharging and receiving cargo, and for naval purposes, were very quickly appreciated. Thus, although the introduction of electric lighting cannot be fairly said to be of earlier date than 1878, or barely fifteen years ago, yet it may be claimed that aboard or in connection with ships it was freely used even during its early incipiency.

Ideal Installations.—To those who are not familiar with the subject it may be stated that, taking a steamer carrying, say, one hundred lights, the plant consists of simply a single dynamo machine, with its small independent engine. This is fixed in the engine-room of the vessel and supplies all the lamps with current. The distribution is carried on through

a series of insulated wires permanently incased. After the installation of this simple plant it calls for practically no attention. There is no trouble with oil and wicks, no lamps to trim otherwise; no precautions are taken because danger is reduced to a minimum. As long as the dynamo is in motion any number of the lights may be turned on or off at pleasure. No regulation of the current is required because the dynamo effects that within itself. Hence, it is clear that, practically, by the expenditure of a little extra coal in the furnace, the ship is brilliantly illuminated with a perfect form of light, and the attendance and the dangers of oil-lamps are entirely overcome.

Ocean-going Installation.—The above is, however, an ideal installation, aboard a steamer navigating rivers or shallow water. The case is rather different when the vessel is of many thousand tons' burthen, and is propelled in all weathers at twenty knots per hour literally *through* the seas; when the huge ship "dips her nose" therein and ships across her decks some hundreds of tons of "green water," sousing and carrying everything before it; when port-hole glasses get stove in and the sea rushes through the opening in a torrent. It is not to be supposed that such experiences—and they are frequently of many days' duration in the Atlantic—do not interfere with the electric light. On the contrary, cables and insulation are very apt to suffer. Leaks of current take place at different points, fire may be possibly set up by such leaks, and the whole installation calls for the constant watchful care of a skilled attendant.

Adaptability of the Electric Light.—But when we compare the trouble that has to be encountered by

the electrician to the disadvantages of the dangers and expense and inferiority of oil lamps, we still find an immense balance in favour of the electric lighting. When we consider the comfort and convenience of the incandescent lamp to the passenger, who, by turning his switch, may obtain a light at any hour, the superiority of the light for reading, and the adaptability of it to the decorative effects in the saloons, we will at once find a reason why electricity as light is now considered indispensable at sea.

The Use of Accumulators.—Although we have briefly touched upon the kind of plant generally used for the production of the current, we have not exhausted the subject. In the case of steamers of moderate size, the engine-rooms and holds below the water-line must be artificially lighted throughout the day. This is accomplished by continuously running the electric plant or a portion of it. Indeed in large passenger steamers the current is never off the wires, night or day, for months at a time. This necessitates the use of steam, which, however, is always ready in such cases, and is maintained for various other purposes about the ship.

But when we take the case of a smaller vessel, perhaps a steam-yacht, the dynamo is moved probably by steam from the main boilers. Therefore, in harbour, the supply from the dynamo fails. It is maintained is such case for many days by means of accumulators. The vessel carries a number of these, and they are kept charged. When the main boilers are inactive they come into play and furnish the current. The dynamo in this case is generally made of sufficient power to run all the lamps and feed the accumulators

simultaneously. There is the additional advantage in this arrangement that only one dynamo is required. Any fault in that would not at once stop the lights. But, notwithstanding the advantages of accumulators they are not generally employed on the larger ocean-going vessels, where, indeed, owing to the duplication of dynamos and the constant supply of steam they are found unnecessary.

Effect of the Current upon the Compass.—When the electric light was first used aboard ships, there were many dismal predictions of disasters at sea owing to the alleged effect of the current upon the ships' compasses.

But although it may be shown that the current undoubtedly exerts an effect upon the needles, yet, when due precautions are taken it seldom causes a falsification of over a point or two. This error is carefully combated by the compass adjuster, by the use of magnets about the ship, and as it varies somewhat, its extent and variation are both familiar to the officers and allowed for. Over and above this, however, large steamers carry an isolated "standard compass." It is placed so high above the deck and cables as to be quite out of the influence of the lighting current. This standard instrument is consulted half-hourly or oftener, and correction of the working compasses made accordingly.

Incandescent Lamps in the Binnacles.—For a long time it was maintained that electric light, although it might be used for side lights, and even for the "masthead," would never be employed for the binnacles in which the working compasses are situated. But, by means of an ingenious arrangement of the lamp and cable, this difficulty has been over-

come, and the effect of the current in the lamp upon the compass may be said to be effectively neutralised. The device is indeed so perfect that most of the largest Atlantic liners have their compasses lighted in this way. Hence it may be taken for granted that a light that can be depended upon so absolutely, has at length banished all other forms of illumination from steamships of any pretensions, and such is indeed the case. Matches, candles, and lamps are regarded as things of the past.

Electricity in the Royal Navy.—Although the current is employed for many purposes in the ships of war, we are here concerned only in its application to illumination, and for signal and search lighting. Indeed, the distribution of electricity in a man-of-war is a complex system compared to the simpler arrangements of an ordinary steamer. While the use of arc lamps is rather rare in ordinary steamers, and search lights are only carried in navigating the Suez and other canals, they are much used in men-of-war. They are also of considerable power, and a special dynamo is frequently kept apart for this purpose alone.

As in the case of large passenger-ships, in war-vessels the current is kept constantly on the wires, and the whole of the vessel beneath the water-line is lighted thereby day and night. The use of electricity in the Navy, for lighting alone, is a subject of considerable importance, and a due proportion of our space is apportioned thereto.

Electro-Motors upon the Lighting Circuits.—A very interesting subject is that appertaining to the utilisation of the current for the running of electro-motors throughout a ship. These are used chiefly for light

work, as for ventilating fans, and on passenger-ships even for moving the rotary hair-brushes in the hair-dressing saloon. But the subject not falling strictly within the lines circumscribed by the word ship-lighting, can only be cursorily glanced at in the limits at our disposal in the following pages.

CHAPTER I.

SHIPBUILDERS' PRE-ARRANGEMENTS.

Location of the Electrical Plant.—In the early days of the electric lighting of steamships, it was considered sufficient to place the plant in some spare corner of the engine-room. There the dynamo and its motor were fixed, generally in a dark and damp position. If it ran well, without any attention, electric lighting aboard that vessel was considered a success. If it performed indifferently, through sheer want of attention, electric lighting was speedily condemned, and a return made to oil lamps.

It may be supposed that such circumstances as the above applied only to very small attempts to illuminate equally insignificant vessels, but such is not the case. Many vessels of over 1,000 tons burthen, carrying propelling engines of over 100 horse-power, were so furnished. If the chief engineer or his mate chanced to be an amateur electrician, so much the better for the electric light, and in which case it usually proved a success. But, as generally happened, neither of them cared to trouble themselves about the innovation, failure was frequently encountered.

Expensive experience has changed all this. Electric lighting is now so universal that a good deal of attention is given to it by owners as well as builders, and even the engineers in charge of the propelling plant

begin to take an interest in dynamos and circuits. The experience gained in the lighting of ocean-going passenger-steamers and men-of-war indicates very clearly that in order to insure the success of the lighting, and the safety of the vessel from fire, the following points must be carefully considered:—

The Dynamo-Room must be separated from the Engine-Room.—It may not at first appear necessary to provide a separate department for the plant, but, notwithstanding, experience has shown that it is not only advisable but economical to do so. The following are the chief objections to locating the electrical plant in the propelling engine-room:—

The insulation of the dynamos, distributing boards, and indicating instruments, suffer severely from moisture, either from below or from the air. If the plant is fixed, as is generally the case, upon the level of the main engine-bearings, it is subject to damage by reason of water, whether occurring from leaks, from the playing of the hose-pipe to cool bearings, or from condensed steam. It is also subject to damage from moisture in the air, due to escaping steam and evaporation. Damage is frequently done to electrical machinery by oil thrown off the main engines. And it may be further pointed out that the high temperature of the engine-room is very unfavourable to the insulation, assisting, as it does, in the gradual deterioration of the insulating material when superadded to the high working temperature of the dynamo itself.

A duly-qualified Electrical Engineer should be appointed to look after the Plant.—At the present time it may appear unnecessary to make the above proposition, since it has of late years been brought home

to shipowners that their regular engineers have seldom the time, if they possess the requisite knowledge, to superintend the electrical work. Hence, in the case of important passenger-steamers, or men-of-war, the electrical engineer and his staff, although classed with the regular engineers, are a distinct body.

It may appear to the uninitiated that nothing can be simpler than to keep a dynamo and circuits in order. However true this may be ashore, where everything is a firm fixture, where surroundings are dry and clean, and where the run of the cables and branches is "bone dry," a very different order of things maintains aboard an ocean-going steamer. Water, salt and fresh—the former the greater enemy—steam from circulating pipes, oil, ammonia vapour, and other foes to insulation are constantly reaching the cables and wires, and the dynamo itself, aboard ship. This necessitates constant watchfulness on the part of the attendant, and the requisite ability to cut out and repair faults in any portion of the plant without delay. When we add to this that in a large steamer or a man-of-war there are frequent calls for fresh lamps, and changes of position of those already fixed, that new circuits have to be run or old circuits renewed in some part almost daily, it will be seen that special attendants are indispensable.

Proper Position of the Dynamo-Room.—It is a mistake to locate the electrical plant at the bottom of the ship. There are many practical reasons for this. Total extinction of the lights aboard a large passenger vessel is sufficient very often to cause a panic itself, and this may easily happen when the plant is situated at the bottom of the vessel through accidents with water or steam from within or without. In

addition to this, the lower position is unfavourable generally to good insulation. It necessitates the cables being carried through the various decks above, and thereby increases their length and resistance, and it wastes the time of the electricians in ascending and descending when on duty.

The best position for the dynamo is undoubtedly about the level of the top of the boilers. We do not recommend a position directly over the boilers. The temperature there is generally too high.

In some of the best of our ironclads the dynamo-room is on the level of the main shaft-bearings, but, although it adjoins the engine-room it is always *separated therefrom by transverse and longitudinal bulk-heads*. It forms, in fact, a separate department.

Although this system has much to recommend it in the case of men-of-war, inasmuch as it insures the plant being well below the water-line, and therefore protected from the effects of shot, yet the case of steamships of the mercantile marine is different. In ocean-going steamers most of the electric-lighting takes effect about the level of the main deck, in the saloons, state-rooms, and deck-houses. It is in this neighbourhood that the cables and wires are most numerous, and the nearer the dynamos are to these the less the cost of running the plant. The risks of extinction and damage are thus reduced.

When plant is duplicated it should, if possible, be kept in separate rooms. One of the great objects of duplicating the propelling plant of an ocean-going steamer is well known to be a precaution against the effects of collision or other damage to the vessel or engines or boilers, so that if one side becomes

useless, the other may still move the vessel. For this reason duplex engines are generally separated by *longitudinal bulk-heads*, as well as by transverse bulk-heads.

In the latest types of ocean passenger-steamers the same system is carried out in the case of the electrical plant. In the case of men-of-war extraordinary precautions are taken to protect all the machinery, and the electrical plant is usually fully duplicated. If the vessel carry one thousand lights there is engine and dynamo-power for two thousand, and the sets are used alternately. In addition to this they are frequently entirely isolated by bulk-heads.

Ocean liners seldom carry a complete duplicate plant, but there is always a partial duplication. Thus, if the vessel have a thousand lamps, dynamos sufficient for one thousand five hundred are generally provided. Experience has proved that in order to insure against accidents this plant should be divided into two equal portions, entirely isolated from each other by iron bulk-heads.

This is the system adopted in the case of the later White Star steamers, where the longitudinal bulk-head separates the two halves of the propelling plant and the electrical machinery. When four dynamos are carried, two of these are placed on either side of the bulk-head.

Specifications supplied by Owners to Shipbuilders generally contain data and dimensions relating to the electrical plant. This part of the ship's machinery was for some years overlooked in specifications, but the increasing importance of the lighting arrangements has proved the advisability of clearly specifying the dimensions of the dynamos and their

engines, together with the space required for accumulators (if any) and instruments, with standing-room for attendants.

The dynamo-engines are sometimes fed by the main boilers, and frequently by a separate boiler, but in many cases receive their supply of steam from the donkey boiler. Specifications should state clearly to the builder, for his guidance, the source of steam. If no source is indicated, he would be justified in so arranging the space for electrical plant as to make it adjacent to the main boilers. In any case the electrical plant should be situated as near as practicable to the source of steam.

Separation of Dynamos from their Engines.—As we have already observed, there are many objections to the placing of dynamos in the main engine-rooms. Now the same drawbacks apply to the presence of the dynamo-engines in a lesser degree. It is usual at the present time to couple dynamo and engine direct. This necessitates, as they are generally arranged, their being bolted to a common bed-plate.

Unless the engines are clean in working, there is an inevitable leaking of steam, a scattering of oil, a great deal of heat, and a general atmosphere destructive to insulation. Although we are not aware of any instance of its application, we are convinced that it would prove of great advantage to separate the dynamo from the engine by an iron partition. There would be no loss of space. The change would only necessitate the use of a "flexible" coupling upon the engine or dynamo-shaft, and, if desired watertight, a miniature propeller-shaft stuffing-box in the partition, through which the shaft would work.

In this way the dynamo-engines might be placed in the main engine-room at a suitable level.

Pre-arrangements for Cables.—It is seldom that the requirements of the lighting engineer can be anticipated by the shipbuilder, except in the case of dynamos and engines, so that the piercing of bulkheads, decks, and so on, is generally left until the running of the cables commences.

Pre-arrangements for Accumulators.—The use of the accumulator is practically confined to the following classes of lighting: Passenger steamers that lie frequently in port and do not maintain steam; yachts, to which the same remark applies. Numerous vessels are furnished with the electric light and yet do not maintain a separate boiler for moving the dynamo-engine. In such case the steam from the main boiler is used. Others supply steam from the donkey or winch boiler also, as well as the main boiler, or either as required. Private yachts are large users of accumulators.

There are, however, numerous instances where accumulators are employed as regulators or as a safeguard, even when steam is constantly available. Their employment makes the duplication of the generating plant unnecessary. It may be further said that in all cases where the dynamo is moved by the main engines accumulators cannot be dispensed with.

Accumulators to be isolated from the Machinery.—The most perfect accumulators are apt to give off certain vapours which are destructive to bright iron or steel work. Hence they should be located in some position, preferably in the waist of the ship, but still isolated above the machinery. Iron shelving, bolted to bulk-

heads, is generally erected for the reception of the cells. The shelves should not be less than than two feet in depth. Twenty-six cells, each not less than twelve inches wide, are necessary as a minimum number of accumulators. There are generally allowed a few inches clearance between them.

The accumulator shelving is afterwards fitted with wooden or other insulating covers and fronts, partially boxing in the cells. The position chosen for an accumulator battery should be well ventilated and lighted, and as cool as possible.

CHAPTER II.

ENGINES FOR SHIP-LIGHTING.

Different types of Engines available for Ship-Lighting.

Reciprocating Single Cylinder.—This is by far the most common type of engine generally used. It is more especially adapted to the installations of small steamers. The engine is usually of the vertical overhead cylinder type, and this form presents, among others, the following advantages:—

(1.) The engine is low in first cost.
(2.) It is simple in construction.
(3.) It occupies but little floor space.

These small engines are usually connected with the dynamo by one of two methods; first by a strap.

Strap-driving is not without its advantages, even if it be shown to have some drawbacks in ship lighting. Its chief advantage lies in the fact that while the engine may move slowly, any required speed may be imparted to the dynamo. There is, therefore, a considerable saving in wear and tear of the engine. Among other points it may be claimed for strap-driving that there is comparatively little danger of burning up the insulation of the dynamo, owing to an accidental short circuit being set up. In such case it usually happens that the strap is thrown off the pulley, or slips sufficiently to save the insulation.

It may be contended that a fuse or cut-out near to

the dynamo would effectually prevent such a disaster as the above, but it must be remembered that small installations are frequently left in the charge of inexperienced persons, and that the position of a cut-out is frequently found bridged across with a piece of copper cable, rendering the device useless. And, moreover, a cut-out cannot save a dynamo from the effects of a short circuit within itself.

Strap-driving is also not without its disadvantages. The chief objections to the use of a strap are, first, the floor space necessary. Short straps may indeed be used, so as to bring engine and dynamo in close proximity, but short straps necessitate the employment of idler pulleys to force the band into contact with a large proportion of the periphery of the dynamo pulley. Otherwise there is scarcely any grip, and slipping at full load becomes a nuisance. The use of the curbing or belt-tightening gear involves considerable waste of power. There is a great strain upon the spindle upon which the tightening pulley rides.

Nothing in the way of straps runs so well as a long open belt. But this is not only generally inadvisable in the case of ship lighting, owing to the space occupied, but it is apt to perform badly in heavy weather at sea. The belt is apt to leave the fly-wheel or pulley. These remarks have reference to the cost of engines and dynamos being placed at different distances apart upon a common level.

If the engine be situated above or below the dynamo at a distance apart between the centres of the shaft of not less than ten feet, it may be a simple matter to drive with a strap, without belt-tightening gear. This method may indeed be said to be the only successful one in the case of ship lighting, when a strap must

be used. The engine is usually situated in the main engine-room, and the dynamo is placed the height of one, or preferably two decks above it, directly overhead. The belt runs in a tunnel, which does not necessarily occupy much valuable space. When a

Fig. 4.

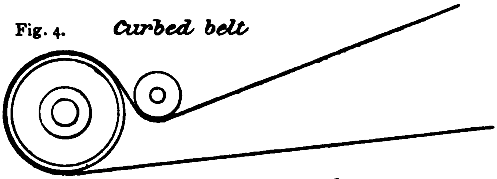


Fig. 5.

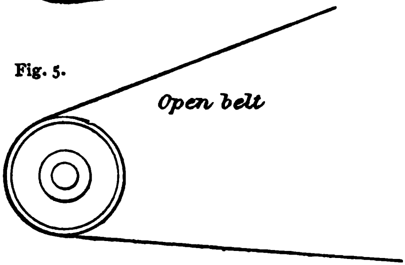
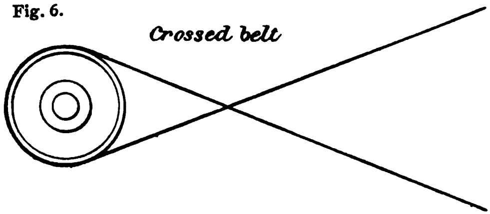


Fig. 6.



belt is rather short and is run open, without tightening gear, its grip upon the pulleys may be increased by simply running it as a crossed belt, and reversing the engine. Figs. 4, 5 and 6 exhibit the arrangements of the belts in relation to the pulley.

Varieties of Belting.—Neglecting various fancy kinds

of belting, the choice for dynamo work is confined to good oak-tanned leather, to leather link belting, and to cotton belting. The latter, when well painted, performs well at sea, and has the advantage of being inexpensive. It is, however, rather difficult to join. Link belting is the simplest in this particular.

There is probably nothing better than a plain leather belt, which should be so carefully scarfed or lap-jointed that its thickness at that part is not increased. In lacing, the method shown in Fig. 7 should be followed.

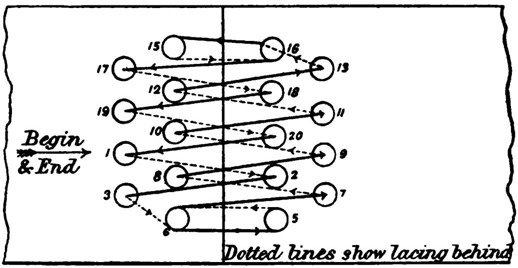


Fig. 7.—Diagram showing Lacing of a Dynamo Belt.

Belting direct from the Main Engine.—This method is much used in yachts, when accumulators are carried as a reserve, when the main engine is at a standstill. It presents the advantage of dispensing with the independent engine and its attendant noise. The main or propeller shaft carries a pulley of sufficient size to move the dynamo at the required speed when the main engine is doing *average* work. The dynamo is generally placed as far from the main shaft as possible, and is usually run with a cross-belt to increase the surface in contact. The dynamo is preferably placed overhead, if possible on the level of the

main-deck. This method of driving is not suitable to the case of vessels liable to encounter bad weather at sea. The inevitable racing of the main engine when the propeller is clear of the water soon destroys a dynamo and a set of lamps. In all such cases the dynamo should be provided with its own heavy fly-wheel, and a belt liable to slip than otherwise is to be preferred. These precautions obviate to some extent the evils of variable driving.

Rope-Driving.—This method is probably less suitable than any other to the case of ship lighting. Although an endless rope, occupying several grooves upon the pulley, and provided with tightening gear, is well adapted to central station work, it is out of place in the atmosphere of a ship's engine-room; yet rope-driving aboard ship is not without its advocates.

Single Engines, connected direct.—Direct connection of the engine-shaft with that of the dynamo is rapidly becoming the standard method of driving. It necessitates, first, that the engine shall run at the same speed as the dynamo; second, that the engine shall be of good construction, capable of rapid self-regulation, and be free from noise. The method further necessitates the use of considerably larger dynamos than usual, because, in order to accommodate the engine, the speed must be slow. The diameter of the armature must therefore be considerable to allow it to attain the required speed. Slow-speed peripheral dynamos are not, however, without some advantages, although their first cost is considerably greater than that of fast machines.

High-speed steam-engines are frequently troublesome. To withstand the continuous high velocity their construction should be of the best. *The reciprocating*

parts should be light and the stroke short. If the construction should be faulty they speedily ruin not only themselves but the armature of any dynamo connected to them. It may be said, in a word, that *cheap high-speed steam-engines are an abomination.* Single-acting engines are suitable for small steamers and for yachts.

Compound High-Speed Engines.—The compound or twin cylinder engines are by far the best for electric lighting aboard ship. They are, to commence with, generally better made then the single-acting engines. They are economical in use, and they yield, bulk for bulk, greater force than single engines. When the cylinders are placed side by side, working on two cranks at right angles, locomotive fashion, the motion is more favourable to the dynamo than is possible with a single cylinder.

Multiple Cylinder Engines.—These are now a numerous patented class; but although in the earlier days of electric lighting it appeared probable that three-cylinder engines would form the most important class for ships' lighting, yet those expectations have not yet been fulfilled. The main advantage of the Brotherhood and other engines of this type appears to be their small bulk, their moderate weight, and their immense capacity for high speed.

Rotary Engines.—Probably the best known of the rotary type are the engines of Parsons (steam turbine), the "Tower," and others. These engines occupy very little space and run noiselessly. They are eminently suitable for installations in charge of engineers who are familiar with the rotary engine in its various forms.

Large Passenger and Mail Steamers generally carry Compound Dynamo-Engines.—These are either of the

vertical or horizontal type, and are made as simply as possible. The horizontal type appears to be most in favour where there is space to spare for them. It should be pointed out that complex steam-engines are not liked aboard passenger mail steamers.

Direct Driving.—It may be said that, almost without exception, direct connection necessitates the providing of a cast-iron bed-plate common to both engine and dynamo. Engines intended for dynamo-driving are generally built upon such a bed-plate, their shaft-bearings being cast solid with the bed. The dynamo is bolted to the same plate, with its axis parallel and is concentric with that of the engine. Rigid couplings are the rule, but some makers prefer to use flexible couplings. Fig. 8 exhibits the arrangement showing a Chandler's engine and a dynamo connected direct.

The chief faults that are apt to occur in the use of a rigid coupling, with direct connection, are want of exact parellelism, so that a slight strain is apt to be imposed upon the dynamo-shaft in bolting the flanges of the couplings together. There is also the objection that direct-driving renders impracticable the usual "end play" of the dynamo-shaft. This end play is of considerable importance, insomuch as it prevents grooving of the commutator, and maintains a distribution of oil in the bearings. A coupling that would be satisfactory mechanically and yet permit of the end play, is much required in ship lighting.

Engines running Dynamos direct must be clean in Working.—The enclosed types of engines are undoubtedly the best for dynamo work, but these are very apt, in the case of cheap engines, to be poorly fitted and finished, since the working parts are not

open to inspection. It is important, however, that the engine shall be clean in working, free from steam leakage, condensed steam, and so lubricated that oil is not scattered about near to the dynamo, instru-

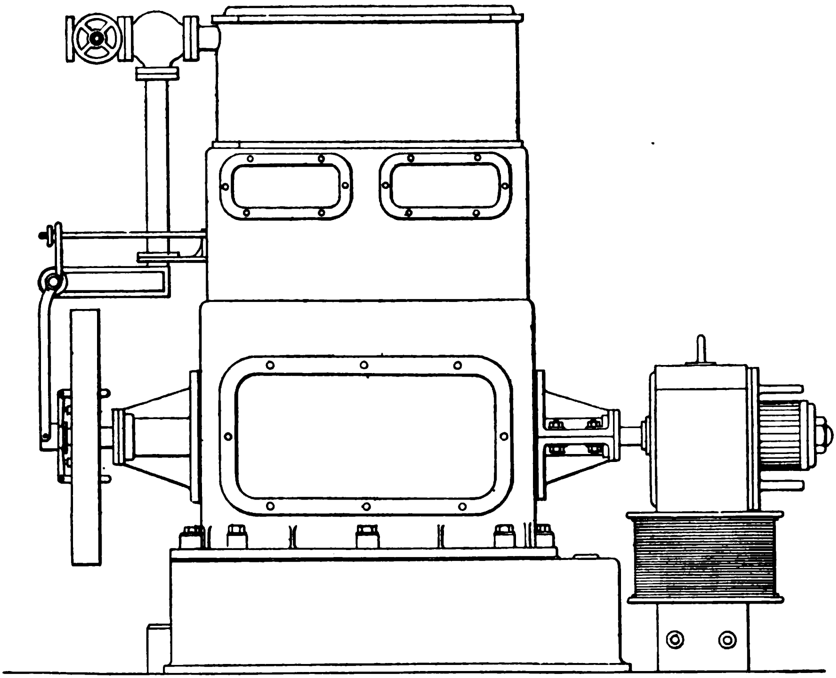


Fig. 8.—Chandler's Engine and Dynamo connected direct.

ments, or circuit wires. When the engine can be conveniently separated from the dynamo by an iron screen, this is well worth doing. It seems to intercept the above enemies to insulation, and also heat radiated from the cylinders and steam pipes.

Insulation of the Dynamo from the Base.—This subject is treated at greater length in a subsequent part of the chapter, but it may be useful to mention here that before the dynamo is bolted to the engine bedplate, a thick sheet of vulcanised fibre, or even asbestos, should be interposed. If the latter is used it should be moistened before being placed under the dynamo. The bolts should be thin in proportion to the diameter of the bolt-holes, and sleeves of fibre or rubber tubing placed over them to prevent metallic contact. Under bolt-heads, also washers of vulcanised fibre, should be placed for the same purpose. The dynamo should, in short, have its frame completely insulated from the bed of the engine.

Speed of the Reciprocating Engines.—The average speed of the single and compound engines may be taken at 400 revs. per minute. The large engines move from 200 revs. to 400 revs., while the smallest attain about 600 revs. The larger engines, running at the lower speed, indicate from 50 to 100 H.P. The smallest, moving at the highest speed, indicate from 5 to 50 H.P. Dynamos to work with those engines must develop their full effect at the average speed of the engine.

Reciprocating engines for ship lighting should be fitted with governors that can be adjusted to higher or lower speed without stopping the engine. The *governor* must also be sensitive, and act quickly when the dynamo calls for more or less power. The Pickering and the Turner-Hartnell governors fulfil these conditions very well. The lubricators must be arranged to permit of long continuous runs without stoppage. Important bearings should be fitted with sight-feed lubricators.

Speed of the Special and Rotary Engines.—Engines of special build, such as Willin's central valve, the "Tower" and "Globe," are capable of much higher speeds than the simple reciprocating types. The advantage of this is that a smaller dynamo running at a higher rate of speed may be used. The first cost is thereby lower than for slow-running plant, but such special engines are more expensive at the outset, and cost more to maintain. The strictly rotary engines may be regarded as a class apart. Parson's Steam Turbine appears to be the best practical representative of this class, and it has been largely used aboard ship.

Steam Pressure available.—The size of the engine to run a given plant will greatly depend upon the available steam pressure. The higher the pressure the smaller the engine required. In large steamers it is usual to run the electric plant off the donkey or pump-engine boiler, and when this is of sufficient size it is usually employed to run the winches when in dock, so that there is a constant supply of steam for the lighting. The lamps are thus maintained alight below deck for months at a time.

CHAPTER III.

DYNAMOS FOR SHIP-LIGHTING.

Practical Requirements of a Ship's Dynamo.—Many makers of dynamos have produced machines claiming to be suitable to the work of lighting sea-going vessels. That few of these have studied the practical requirements in such a machine, is shown by the small number of dynamos actually suitable and used by shipowners for the purpose. It is one thing to build a machine that might be used successfully upon a ferry steamer, and quite another to design a dynamo capable of the work aboard an ocean-going vessel, exposed to bad weather, and away from shore assistance for weeks or months at a time.

Continuous or Alternating Current.—Attempts have frequently been made to employ the alternating current aboard ship. They are mostly failures. The continuous current offers so many advantages that it is improbable that alternators will ever be used in ship-lighting. The continuous current is well adapted to work through the single wire system of distribution, so much used in ship-lighting. Volt and ampère meters of simple types can be employed. The danger from personal shock is very much less than is the case with alternating current, or is entirely obviated when direct or continuous current is used. And it should be borne in mind that as steamships

are almost invariably built of iron or steel, the chance of closing a circuit through the body is much greater than in the case of a shore installation. There are metal contacts in every part of the ship, and a high voltage of alternating current aboard such vessels, even if insulation be of the best, is a very questionable advantage. There is still further the question of distributing power to fan and other motors by means of electricity, which is quite simple with the continuous current, but would be almost impossible if alternating currents were employed. It can, further, be shown that less insulation will suffice for continuous than for alternating current on shipboard. Hence the first cost of wiring for continuous current is the lesser of the two.

Regulation—Compound, Shunt, or Series Dynamo ?—Given a continuous current dynamo, the question arises whether it should be compound, or shunt, or series wound. It is incorrect to say that any one of these types is adapted to all the purposes of ship-lighting. But for the running of incandescent lamps in parallel there can be no question that the compound wound dynamo is to be preferred for ordinary purposes.

For the benefit of the uninitiated it may be useful to explain what is meant by shunt and compound winding, because both types of dynamo are used in ship-lighting. When a dynamo is required to maintain a fairly-constant *current*, a condition essential in running arc lamps in series, the circuit of the armature is continued through the field magnet coils, so that the whole forms practically a single path. The circuit of the lamps is included in this path. The electricity evolved in the armature therefore flows

through it to the magnet coils, and from them to the lamp portion of the circuit, and so back to the armature.

This is known as series winding in the machine, and series working in the lamp part of the circuit. It is largely used for arc lamps, because such a dynamo tends to evolve more or less *current* of itself, as it is called for by the lamp portion of the circuit. Such a dynamo works very well so long as the resistance of the external part of the circuit remains fairly constant, but it fails if this varies much, because it is incapable of maintaining a constant pressure or potential under varying conditions of the circuit. The field magnets of a series dynamo are wound with thick wire, forming a single length of wire, through which the whole of the current passes.

In the *shunt*-wound dynamo two paths are open to the current as it leaves the armature. If two paths be open to a current it does not choose either entirely. It divides itself between them. That portion which offers the lesser resistance carries the larger proportion of the current. In the shunt dynamo the two paths are, firstly, the external work, or lamp portion of the circuit, and, secondly, the field magnet coils. The latter are composed of thin wire of considerable length, and offer considerable resistance to the passage of the current. Therefore, a small proportion of the current only flows around the magnets. The latter, indeed, form merely a shunt, loop, or by-path to the work circuit, in which most of the energy is expended.

The effect of this arrangement is very strikingly manifested if a shunt-wound dynamo be used to light a few arc lamps arranged in series. If we commence

by switching on one lamp, a given proportion of the current will flow through it, and a proportion, dependent upon the resistance, will flow in the field magnet coils. If we now switch in another arc lamp the effect will be to nearly double the work resistance, therefore a smaller proportion of the current will flow therein. But, since we have increased the work resistance, the proportion it bears to the field magnet resistance is relatively greater, and the effect will be to send a larger proportion of the current through the field magnet. Hence, the latter, by evolving a more powerful magnetic field, will cause the armature to give out a relatively powerful current, and the call for increased energy, by reason of the added lamp, will be promptly met. In this way, lamp after lamp may be switched into the circuit, and the dynamo may be shown to evolve exactly the amount of energy required, and at the proper time. If the lamps be switched off, the effect will be exactly the converse of the above.

It should be pointed out to those not familiar with the subject, that it is pressure, or electro-motive force that is required to vary, when resistances are switched in or out of circuit. The pressure depends greatly upon the strength of the field set up by the magnet. Increased and diminished current will follow corresponding changes in the pressure.

But although it would appear from the above that a shunt dynamo is adapted to the working of arc lamps in series, yet in practice it is seldom used for this purpose, chiefly by reason of the comparative slowness of the responding power of the field magnet when rapid changes of pressure are called for by the arc lamps. The long fine coil of the magnet has too

much inertia, so to speak, its capacity for storing energy is so great that the change from weak to strong, and the opposite, is but slow. The shunt dynamo is, however, admirably adapted for the lighting of incandescent lamps.

Compound or Composite-wound Dynamo.—For the benefit of those who have not the leisure to study the nature and effects of the various windings of machines it may be useful to state here, briefly, the nature of the winding in an ordinary compound ship's dynamo. We have already seen that a series-wound machine, as used for arc lamps, is admirably adapted for that purpose simply because its field-magnet coils carry the whole of the current, and are short and of thick wire. The arc lamp varies its call for current or pressure frequently and rapidly. If the carbons in the lamp happen to get too far apart, the resistance of the *whole* circuit will thereby be increased, and the light will fall off in intensity and volume. Hence, the current round the field magnet being weaker, the magnetic field will also fall off.

If at this point outside help does not step in, the current falls off altogether. But, as the field becomes weaker the armature calls for less energy from the engine driving it, and its speed therefore tends to increase; this is followed by increased pressure in the circuit, and the balance is restored. There is also in most arc lamps a compensating arrangement to assist this balancing effect. But it will be seen that the motor driving the machine is to a great extent the regulator. It is also evident that the series-wound dynamo is very quickly influenced by changes in the working part of the circuit. It is this *sensitiveness* that is taken advantage of in a compound dynamo,

together with its capacity for maintaining *the current* constant under changes.

We have already seen that a shunt-wound machine is far from sensitive. The great capacity of its exciting coils causes it to lag behind and not to respond quickly to the changes in the lamp circuit. But it has very great capacity for *maintaining the pressure.* It is in fact regarded as a *constant-potential* dynamo. The shunt-wound machine performs fairly well in lighting incandescent lamps, but it is not perfect. As lamp after lamp is switched in (in parallel across the main leads), the resistance of the exterior circuit becomes diminished. Therefore a larger proportion of the current flows across the mains and a smaller proportion through the by-path or shunt. Hence, the dynamo tends to become weaker and not stronger. The effect is not, however, very great, because a great many incandescent lamps added to the circuit would only diminish its resistance slightly, because their own resistance is very great, and only a trifling current can flow through them. There is also the fact, in reserve, that as the magnetic field becomes weaker less power is demanded of the engine, and the latter tends to drive the dynamo more quickly, helping to restore the balance. But, notwithstanding this, the shunt dynamo is not generally used on shipboard unless the vessel carries also a set of accumulators for storage purposes. In this case the shunt machine is indispensable.

But since the series dynamo is admirably adapted for maintaining the *current* constant under varying load, and the shunt machine, as we have seen, is equally well fitted to maintain *potential* or *pressure* uniform under a varying load, it appears that if the

attributes of these two types could be *combined* we should have a perfect regulator. Such indeed is the case in the compound or composite field dynamo. Its field magnets are wound exactly as for a shunt machine with a long coil of thin wire. Superimposing is the series winding, consisting of a limited number of turns of thick wire. The former is connected so as to form a shunt or by-path to the main current. The latter is placed directly in the main circuit, as in a series dynamo.

The effect of compounding the winding is to cause the machine to act as follows:—As lamp after lamp is switched across the mains, the call for current increases in proportion. Since the resistance in the lamp leads falls, as lamps are switched in, this implies diminished resistance of the series coils of the magnet, and a greater current flows therein, giving the requisite increments of strength to the field magnet and thereby increasing the current as required. Meantime the shunt coils *maintain the pressure* nearly constant, so that the two great requirements of an incandescent lighting dynamo are fully met. So perfect are some of these machines that one lamp or five hundred can be turned on, yet their brightness shall not vary, nor does the speed of the dynamo to any great extent. A good compound dynamo intended for use aboard ship should be capable of lighting ten per cent. of the lamps, and all the lamps, *with equal brightness*, if the two sets are tried separately.

Slow Speed an essential general Condition.—Experience has shown that fast-speed dynamos for ship work are very unsuitable to ordinary conditions. The chief fault of a high-speed plant is no doubt its

liability to get out of repair. This fault is a general one, distributed under several heads. Commencing at the engine, a high-speed dynamo requires a fast engine. This of itself is more apt to get out of gear than a slow-speed engine. There is, moreover, the great objection on passenger steamers, to the noise inseparable from the usual kinds of fast steam engines.

It is true that a slow engine may be used to move a fast dynamo, but not without the interposition of some kind of connecting gear. Belting is the best of these. Straps either require floor space, which is usually very valuable, or they waste power by being curbed round the pulley to get the requisite grip. Instances could be given when the dynamo is placed vertically over the engine, as mentioned in a previous chapter, and in which case the objections to belts are greatly overcome, but these are the exceptions rather than the rule. It may also be mentioned that with some kinds of rotary engines or steam turbines the objection of the noise emitted by the engine is obviated.

A fast-running dynamo is, in the first place, unsuitable at sea because it is generally a small machine in proportion to its work, and therefore performs constantly at "high pressure." This in itself is a fault when such a machine is placed in the hands of inexperienced men. But the main objection lies in the fact that the commutator or rubbing portion of the machine demands much more attention in a fast than in a slow dynamo. This skilled attention is not easily found aboard ordinary steamers, and even where an electrician is carried it is a point that is very apt to cause stoppages.

The internal structure of the armature is another point at which fast-speed dynamos are apt to fail. The centrifugal force is so great that the coils are apt in course of time to burst their wrappings and become otherwise displaced. The constant vibration of a fast-speed engine also effects undesirable changes in the insulation of the armature. The bearings of the dynamo are another point at which there is apt to be trouble. Unless well fitted and efficient these are apt to heat and cause probable stoppages. These are a few, but not all of the objections not unjustly urged against high-speed dynamos, working up to their full capacity. It may be well to define here what is meant by high speed. Any rate of rotation above 500 revs. per minute may be considered high for ship-lighting purposes. This speed may indeed be considered as the limit, more especially when the machine is connected direct to the engine. The lower the speed the greater the economy, generally speaking, from a mechanical point of view. As an offset against the advantages of low speed we have to consider that slow-speed dynamos cost more, weigh more, and are more bulky than high-speed machines.

Size, Capacity and Speed of Dynamos.—The capacity of similar dynamos has been variously estimated as: (1) proportional to the cube of their linear dimensions; the work wasted in magnetizing the field magnets proportional to the linear dimensions, while the work wasted in heat in the armature is proportional to the square of the linear dimensions; (2) assuming the speed of rotation to vary inversely as the linear dimensions so as to put all machines under equal conditions with reference to centrifugal strain,

it is assumed that the relative output should vary as in the following table, which gives the leading particulars of two dynamos of different sizes—both fast-speed dynamos for ordinary lighting:—

Diameter of Armature	10 ins.	15 ins.
Revolutions per Minute	1000	670
Number of Glow Lamps	150	620
Weight (cwts.)	10	34
Price	£100	£276
„ per Lamp Capacity	13s. 4d.	8s. 11d.
Electrical Efficiency (per cent.) . .	80	89

Requirements at the Armature in Ships' Dynamos.—Armatures are either furnished with their conductors by means of a process of winding with wires, or by a building process consisting of fittings of copper bars. The low tension required in incandescent lighting, which is seldom above 110 volts, enables the armature to be made of very small resistance. In other words, the conductors composing it need only describe a small number of turns to evolve the necessary potential. Hence, the aim of the dynamo builder is to simplify the conductors as much as possible, so as to render them accessible in case of repair. This is best accomplished by the system of building by means of copper bars, dispensing entirely with wires. It is probably not too much to say that all ships' dynamos should be furnished with bar armatures, and that the more complex wire coil windings be entirely excluded from this type.

Requirements respecting the Commutator.—This part of the armature, consisting of a copper cylinder divided into sections radially, should be of the best construction in a ship's dynamo. The commutators that wear best are composed of hard drawn copper, or preferably, phosphor bronze. The insulating sub-

stance forming the divisions between the radial sections should be mica. The surface of the commutator should be "dead true," and quite smooth. The cylinder should be of sufficient length to accommodate at least one pair of brushes to take off the current from each diameter.

A commutator that is furnished with one brush only on each diameter should be rejected. The object of providing two or more brushes upon each side is not only to insure effective collection of the currents. Its chief object is to provide a means whereby the attendant may withdraw and trim his brushes, one pair at a time, and yet not be under the necessity of stopping the dynamo. A dynamo intended for the running of from 3 to 500 lights should be provided with at least three brushes a side, or three distinct pairs. Each brush should be fixed upon its own independent swivel, and have its own holding-on spring. This arrangement insures that any brush may be removed and replaced without disturbing the remainder.

The later types of brush rockers are further furnished with holding-off springs. The complete bracket, carrying the pairs of brushes, must be capable of partial rotation round the armature shaft. It is usually attached to a ring, which moves freely upon a concentric shoulder-piece, forming part of the shaft bearing at the collecting end of the armature.

Requirements respecting the Magnet Coilings.—In a dynamo to be put aboard ship, which may possibly be engaged trading abroad, out of the reach of electricians' workshops, particular care should be taken to observe that it is so arranged as to be easily taken apart and repaired. The chief requirement of the

field-magnet coils, next to their being thoroughly insulated and warranted not to overheat at full load, is that each distinct coil shall be wound upon a shell, so that it may be slipped off the core of the magnet when required.

A dynamo that has the wire wound direct upon the magnet should be rejected. Each coil should be distinct, and the arrangements for connecting the coils together should be massive and effective. In addition, to facilitate reconnecting, parts that should come together should be stamped with like letters or numbers, so that no mistake may be made in reconnecting. It is a safe plan to carry one spare field-magnet coil ready for placing upon the dynamo in case of damage, mechanical or electrical, to the original coils. In many cases this safeguarding against accidents is carried so far that a spare armature also is carried, ready to be fixed in place of one damaged or burned by accidental short-circuiting.

Requirements respecting the Insulation generally of Ships' Dynamos.—If the insulation of a dynamo to be used ashore should be good, that furnished in the case of a ship's machine should be much better. The chief reasons for this requirement will be manifest when we consider that sea-going electrical plant is generally in charge of ordinary engineers, who, however skilled in their own profession, cannot be expected to include therein a minute knowledge of electrical subjects. Hence, such dynamos should be so insulated as to provide as far as possible against the effects of over-running, and consequent over-heating, and also those that occur when an accidental short-circuit is made. Main fuses or cut-outs are generally regarded as a safeguard against the acci-

dental burning up of the dynamo, and this is true when the plant is run by experienced persons.

But main cut-outs are as frequently a delusion and a snare. It is a common experience to find that, after a main fuse has "blown," a convenient bit of cable or copper strip is screwed into its place; or, possibly, if the original material, tin or lead, wire or ribbon, be replaced, it is of such heavy section as to be useless as a protection to circuits or dynamo. The latter device is so commonly adopted at sea that a little inquiry concerning it elicited the information that the fusible ribbon supplied for the cut-outs "was always burning out," and in order to save the trouble of replacement, double and treble layers of ribbon would be fixed in the cut-out. It obviously speaks volumes for the excellence of the insulation in dynamo and circuits that it should be capable of withstanding such treatment. It is conceivable that in some cases fuses are made so light as to "go off" on the slightest provocation, but in most instances the complaints against them by inexperienced persons are due to allowing the engine to race, or permitting such serious leaks in the wires external to the machine as to cause partial short-circuits and considerable overheating of the wires.

Ships' Dynamos in High Temperature.—Reverting to the matter of insulation, it should be borne in mind that a ship's dynamo is very apt to be placed in a hot position in the vessel. The temperature of the air surrounding the dynamo is frequently as high as 130° Fahr. When the machine's own heat is added to this it is conceivable that a condition is attained never contemplated by the builder of the machine, either in selecting his insulating materials or in deter-

mining the thickness of the coatings. Hence, ships' dynamos should be so insulated as to withstand a high temperature.

Ventilation (Internal) of Ships' Dynamos.—The above considerations point to the necessity for good ventilation within the machine itself. The armature should be freely ventilated, so that the air is drawn in at the ends and expelled at the periphery, through numerous openings. Ventilation of the field-magnet coils is seldom thought of, but it is of considerable importance. The most effective arrangement is that wherein the rotation of the armature forces air through the field magnet itself, or at least through recesses provided in the coils surrounding it.

Journalling of the Armature Shaft.—A dynamo that is liable to heat at the journals is always a source of trouble aboard ship. There is a great craze abroad for the extension of the journals, so that they are very frequently made too long. This usually results in waste of power, and the production of undue heat, due chiefly to the difficulty of fitting such long bearings to perfection. Further, armature shafts are frequently fitted so closely in their brasses that there is absolutely no space for the lubricant, and overheating is certain to ensue. This fault is one of the most troublesome in some otherwise excellent dynamos. It not only renders effective lubrication difficult, but renders the end-play of the shaft impossible. This end-play should be at least one-fourth of an inch in extent. It prevents grooving of the commutator by the brushes. A shaft that exhibits an excellent fit when cold will probably run dry and cause abrasion after it attains its working temperature.

Typical Ship's Dynamo.

The number of dynamo builders claiming that their particular patterns of machine are adapted for ships' use is very great. However well founded these claims may be, the task of describing even a small proportion of the machines does not fall within the lines of the present volume. Careful reference to the practical requirements of a ship's dynamo, sketched in the preceding pages, will serve to assist in determining whether any particular machine is so designed and built as to be likely to suit the condition required aboard ship.

With particular reference to the general design of the dynamo, it is noticeable that with one or two exceptions they possess field magnets having their poles either bolted to the bed-plate or standing upright. These two kinds of machines are known as the under-type and over-type respectively. The under-type possesses some points of advantage, the chief of which are no doubt the low centre of gravity of the moving parts and the convenient position of the shaft when the dynamo is to be direct driven, especially by a vertical inverted engine.

The placing of the bearings directly upon the bed-plate also tends to reduce and absorb vibration. But it should be pointed out that all under-type bi-polar dynamos are subject to a source of loss. Since the poles of the magnet are bolted to the bed-plate (with footsteps of zinc or brass interposed), it is clear that there is a tendency on the part of the bed to close the magnetic circuit.

In other words, lines of force will strike into its mass and form a kind of magnetic short-circuiting.

The interposition of even a thick plate of non-metallic substance will not obviate this inconvenience, and it is therefore certain that, under ordinary conditions, such dynamos are under a disadvantage in respect of the perfection of the magnetic circuit. Whether this source of loss is balanced by the obvious advantages of the under-type method of construction we will not venture to decide, but it is indisputable that under-type dynamos have performed very well aboard ship.

The over-type is of later production. In this class the magnet, which is bi-polar, lies with its poles upward, the bed-plate forming the yoke or junction piece across the opposite ends. It will at once be seen that this position secures the magnet against loss, there is no short-circuiting of the lines of force. It necessitates, however, the raising of the armature shaft to the height of the axis of the magnet poles. There is no objection to this, provided the standards and bearers are made of sufficiently massive construction to insure rigidity in running. The height from the base is rather a disadvantage, but it can be reduced to a minimum by making the field-magnet limbs short, and broad or wide in proportion.

The over-type dynamo is generally regarded as the most perfect, generally speaking, that has yet been devised, and it appears to be only a question of time whether it will become almost universal in ship-lighting in cases where a machine of moderate capacity suffices.

Still another class of dynamo is likely to be largely used in ship work. This may be regarded as an intermediate type, after the pattern of the "Manchester" or Hopkinson-Mather class. In this pattern the magnetic circle is complete within the body of the

magnet. It is a metallic circle with two "consequent" magnetic poles concentrated at the required points upon a line passing vertically through the armature, a method originally employed by Gramme, but subsequently improved. This method of construction allows

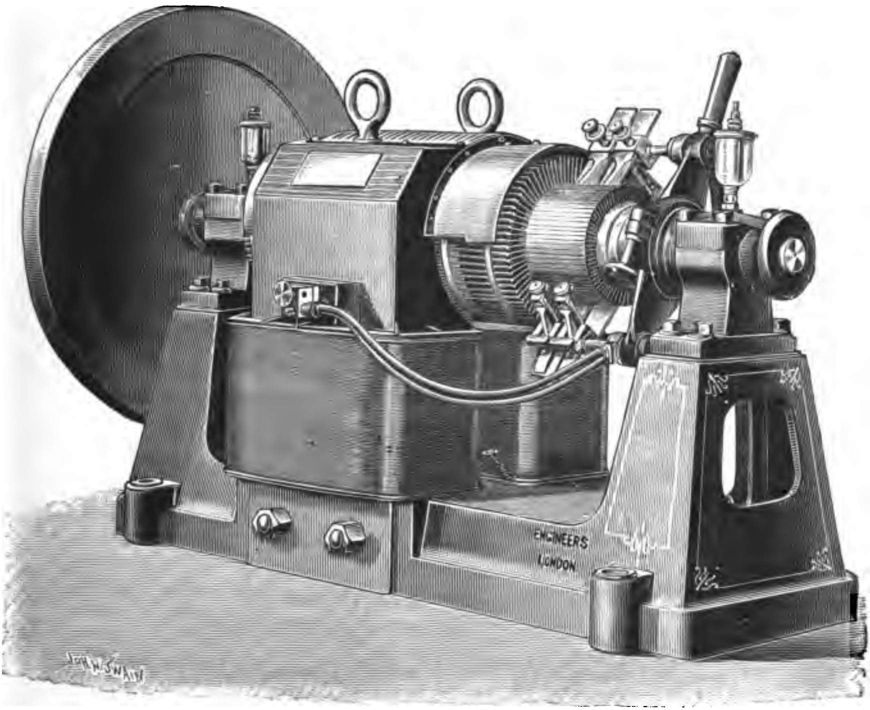


Fig. 9.—Kapp's Over-type Dynamo.

of the armature being placed low down, and it obviates many of the faults of both the under and over-types. But it is not therefore to be assumed that the intermediate type is perfect: a perfect dynamo does not exist.

The above class of machine has been supplied to several of the Atlantic liners by Mr. Crompton, who, however, employs two distinct pairs of exciting coils, a pair to each side, somewhat after the manner of Seimen's original horizontal pattern dynamo.

Reverting to the type of dynamo depicted in Fig. 9, which represents a dynamo of the smallest size, the great compactness and high efficiency of this class appear likely to secure their adoption very generally for ship work. They occupy but little floor space. The centre of gravity of the moving parts is low, giving great steadiness in running and ease of fixing. Efficient ventilation of the armature is secured, which enables the machine to be worked with the full load without overheating. The bearings are all gun-metal of sufficient length, and the shaft of Bessemer steel. This dynamo has a very intense magnetic field, which is not dissipated by neighbouring masses of iron. The commercial efficiency is as high as 93 per cent. in the larger sizes. The commutator is built of hard copper bars, insulated with mica, and under full load there is no sparking at the brushes. Machines for ship-lighting are either shunt or compound wound. The former is used when there is a battery of accumulators. The compound machines are self-regulating from one lamp up to the full load.

Kapp's Dynamo.—Fig. 10 is a longitudinal section and plan of a Kapp machine of the over-type, and having a drum armature 11 inches in diameter by 16 inches in length. The foundation or bed-plate and the bearing standards form one casting. The field-magnet cores and pole pieces are of wrought iron, bolted to the foundation as shown. One of the pole pieces is shown in section in the plan, the gap for the other

being unoccupied. The connecting bolts pass through both pole pieces. Reference to the sections of the shaft bearings will show that a good deal of attention has been given to the lubricating arrangements and the device for draining off waste oil.

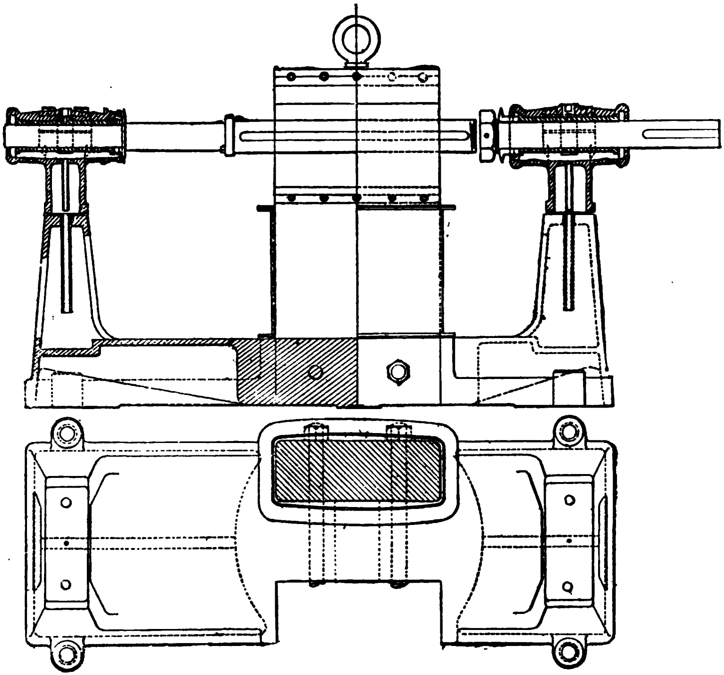


Fig. 10.—Kapp's Dynamo, Longitudinal Section.

Reference to Fig. 11, which is a transverse section, will render the arrangement of the parts clearer. The metallic shells upon which the magnet-exciting coils are wound are shown in section upon the limb to the right. They may be slipped off the pole pieces when the extension of the latter, shown bolted to the ex-

tremities of the curves, are removed, or obviously the coils may be removed by unbolting the pole pieces or cores from the foundation. This is an admirable arrangement, since it permits of the removal of the coils for repair without undue loss of time. In the machine under review the dimensions of the field

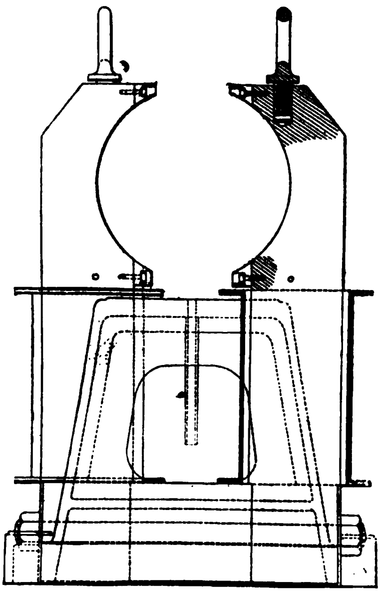


Fig. 11.—Kapp's Dynamo, Transverse Section.

magnet are 15 by $5\frac{3}{4}$ inches: section of core 86 square inches. The coilings are as follows. Shunt windings, each limb, 11 layers of 139 turns of ·056 in. wire. Series windings (compound machine) 23 turns of copper tape ·480 inches by 130 inches. The fine wire on the two limbs is in series, the copper tape in parallel.

A longitudinal section through the armature is represented in Fig. 12. Its core is built up of soft iron disks or washers, having a radial depth of 2⅜ inches and a total diameter of 11 inches; section of the core 62·5 square inches. Throughout the length of the disk space there are distributed three pairs of ventilating disks, having driving horns projecting sufficiently to carry the peripheral windings. The windings or conductors consist of 120 copper bars, each of 46 square inches in sections, and having a re-

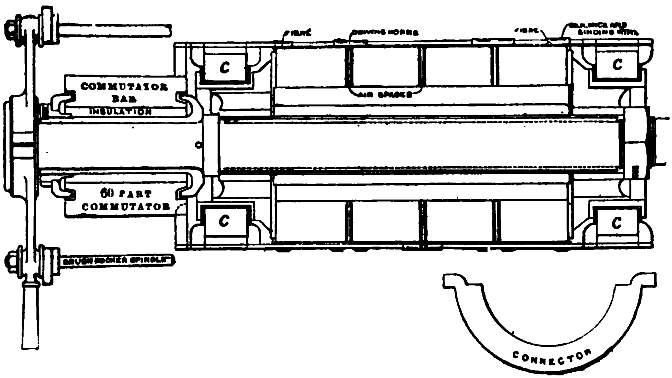


Fig. 12.—Kapp's Armature, Longitudinal Section.

sistance of ·014 ohm. These are formed into loops or diametral pairs by means of arc plates, 50 mils thick by 1⅝ inches deep, called connectors. One of those is represented separate at the lower part of the figure. The tags at the ends of the connectors are twisted at right angles to its plane.

Each pair of bars has its own connector; their position when packed together and insulated at either end of the armature is shown at C C. The commutator consists of 60 bars of hard-drawn copper insulated with

mica. The whole forms a complete cylinder. The bars are grooved at either end as represented. Into the grooves fit the cup-like flanges of the binding rings and sleeve shown. When those are screwed up upon the thread cut upon the shaft, they bind the whole into a compact cylinder. The brushes are carried upon a rocking frame of the form represented. It is capable of motion co-axially with the shaft, but upon a separate ring cut upon the bearing at that end of the armature.

The whole machine is an excellent example of our best English dynamos. Its output at full load is 21 kilowatts, or 105 volts, 200 ampères when run at a moderate speed. This dynamo would suffice to light nearly 400 lamps, each of 16 candle-power.

Ship-Lighting "Sets."—It has become the custom with the larger makers of dynamos to manufacture also the direct-coupled steam-engines required to drive them. Those are sold as "complete sets." Direct coupling of the dynamo does not always imply inflexible bolting together of the shafts. Several builders supply friction couplings, and those have this advantage, that they can be so adjusted that any abnormal load thrown upon the dynamo may cause slipping at the coupling and save the insulation from burning. This class of coupling and also a running friction as used by Messrs. Crossley with their gas engines, is now supplied by the Brush Company in the case of their "Victoria" dynamos. This latter kind of gear would appear to be very suitable for ship work, provided the few objections now held against it could be overcome.

CHAPTER IV.

MANAGEMENT OF SHIP DYNAMOS.

Precaution against Vibration.—Vibration caused by the racing of the main engines in bad weather will cause faults to appear upon the surface of the commutator, unless the dynamo be thoroughly bedded. There will also be a troublesome tendency to jar the terminal and brush screws loose, should there be any freedom between the dynamo and its foundation.

Examination for Serious Faults.—Dimming or fluctuation of the light, when it is not due to leakages from the mains or branches, will generally be found to be caused by some short-circuit within the dynamo itself. These faults may generally be found to be due to one of the following causes :—

Short-Circuit in Field-Magnet Coils.—When the dynamo is running, the coils should be felt for temperature. If one portion is very hot and another cold, it is certain that there is a short-circuit in the cold coil, by reason of which the current does not pass through it, and the excess is thrown on to the hot coil. The fault is generally due to contact between some part of the cold coil and the metal-work of the machine, causing a fault which passes current away to another fault upon the hot coil. It is well first to ascertain that the connecting spirals leading to terminals and connections are fully insulated from each other, and from all metal-work.

To test for short-circuit to the metal-work, a galvanometer and cell may be used. The cell, galvanometer, and a length of wire are connected to one end of the magnet coils. Contact is then made with the wire to any exposed part of the metal-work. A deflection on the galvanometer indicates that the magnet coil is in contact with the metal-work. But a simpler method consists in running the dynamo, connecting a length of wire to one terminal at a time, and touching for an instant any exposed part of the metal-work. A spark given off at the end of the wire indicates a short-circuit. In case of a short-circuit of this kind, when it cannot be reached from without, the unwinding of the whole of the magnet coil may be required, as such a fault is generally due to a breaking-down of the insulation between the inner, or end coils, and the metal reel or sheath separating them from the iron of the magnet. As a rule, however, such faults are generally due to careless connecting at terminals, or to the elastic spirals there touching metal-work.

Failure to Excite.—When the dynamo is started, and the field magnet does not excite, there can be no current given off by the machine. The failure to excite is due to there being no current in the field coils. This will usually be found to be due to imperfect connections. The brushes may not press upon the commutator. The connections of these to the terminals are not complete. The connection between the coils is imperfect, or some part of the magnet coil is broken through or cut—there is, in fact, an incomplete circuit. Commencing at the brushes, it is well to examine all the points.

Failure to excite may be due in rare cases to the

residual magnetism of the field being too weak. It may be due to some serious fault in the armature. The commutator may be coated with charred oil and impurities. These may have become bedded in the insulation between the segments, especially if the former be composed of asbestos, as is frequently to be found in the earlier dynamos. In the case of a shunt-wound dynamo—having no series coils—failure to excite may be due to there being no resistance between the terminals. Shunt dynamos may sometimes fail to start work when a conductor of no appreciable resistance joins the terminals. This is due to the fact that whatever current is generated passes through the interpolar wire, and little or no current in the field coils.

This fault may sometimes occur when a shunt-wound dynamo is connected to a single arc lamp; the carbons being in contact, the resistance is very small. In such case, a small resistance-coil may be switched into the circuit for a moment until the light is shown in the lamp. Some arc lamps are furnished with a resistance of this kind, cutting itself out automatically when the arc is started. But the chief causes of failure to excite are weak residual magnetism—broken circuit—imperfect contact, or short-circuit. A short-circuit in field-magnet coils may generally be noticed by there being more sparking at one brush than at the other.

Armature Faults.—Dimming of the light may indicate a short-circuit in the armature. This may generally be detected by testing the temperature of the coils one by one immediately after stopping. When a short-circuit occurs, the coil will not deliver its current to the lamps. The current circulates in

itself, and the result is great heat in the coil. After a time, if the fault should remain undetected, the heat will increase so as to burn off the insulation. This stage will be indicated by smoke arising from the armature, and by a smell of burning varnish.

Such a fault is sometimes due simply to particles of metal bridging across the insulating interspaces of the commutator. It may be due to copper dust between the connecting-wires from the commutator to the coils, or to a dead contact between the first and last wires of the coil. Some of the best dynamos now built for ship work are so arranged that a faulty coil may be removed from the armature, and a new one put in its place, in a very few hours. This is a very great advantage in a sea-going dynamo. Faulty armature is very generally the result of bad or ignorant treatment of the commutator.

Broken Wire in Armature.—A short-circuit in an armature often commences by a breakdown of the insulation at a weak place, when there exists a great difference of potential. This results in the setting up of a small arc. The arc may be insignificant, but it will in time certainly burn away the wire at that point, causing a complete break. These internal breaks are difficult to locate. Their existence may not be suspected for some time, until the dynamo begins to fail to give its usual current. Internal breaks are tested for by means of a magneto-detector, or a battery and a galvanometer. It is necessary to know the plan of the armature, so as to be able to locate the ends of the coils. As a rule in drum armatures the extremities are connected to exactly opposite segments of the commutator.*

* Plans of the connections in all the ordinary armatures are given in Chap. XI. of "Dynamo Construction."

The battery or magneto-connections are to be established through a galvanometer between the segments representing the ends of the armature. If there is a fault no deflection will occur. Should there be a weak or partial deflection it may be due to a break partially bridged across by copper powder, offering great resistance. In testing for faults in the armature in this way, it is necessary to make sure that the points of contact selected really do represent the extremities of the coils.

In Gramme or ring armatures *adjacent* segments of the commutator generally represent the extremities of the coils. It is advisable that every attendant upon dynamos should be furnished with a plan of the armature connections by the builder of the machines, so that he may be enabled to locate short-circuits with certainty.

An internal fault in a coil usually necessitates the replacement of that coil, and it is a rather serious fault when it occurs in a drum armature, wire wound, according to the Alteneck or Frölich method. Sharp bends in the wire are frequently the cause of such internal faults. Hard-drawn copper will not withstand sharp bending without showing some flaw upon the outside of the bend. When a fault cannot be located, owing to the winding of the armature being unknown, all connections between the armature coils and the commutator may have to be broken. It will be necessary in doing this to number each wire and each corresponding segment of the commutator for proper replacement.

Then it will be a simple matter to determine the extremities of any particular coil. This can be done by connecting the magnets or battery and galvanometer

to one of the extremities, and touching each of the others in succession with a wire leading from the remaining terminal of the galvanometer. A deflection of the needle will indicate the other end of the coil, generally speaking, but a deflection *may* be got possibly by reason of a short-circuit between two coils which should be quite distinct. In testing ends in this way, it is necessary to so separate them that during the test any pair does not happen to come into contact.

Bar Armatures, that is, armatures in which the place of the wire coil is taken by single bars or strips of copper, are not so liable to faults of short-circuiting as the wire-wound armatures. Bar armatures are especially well adapted for ship dynamos. Their great advantage, apart from their freedom from faults, lies in the fact that any bar may be removed and freshly insulated by the ordinary engine-room artificers while at sea. This operation is not difficult, while the same process in the case of a wire-wound ring or drum is both lengthy and demands much greater skill.

The removal of a bar from a drum armature is comparatively easy, while the same operation as applied to a Gramme armature is more difficult. In either case it is accomplished by first exposing the whole length of the armature. This can be done in one of two ways. The field magnet may be separated, and the top of it—in the case of a horizontal type dynamo—lifted up, or, in the case of an over-type dynamo, the armature may be removed from the main casting lengthwise.

But in many dynamos of the over-type, the whole length of the armature may be rendered accessible by merely unbolting the brass connection-piece

between the upper horns of the field magnet. It is better to leave the armature in its bearings than to remove it. The exterior bindings or bands surrounding the armature must in most cases be taken off. These require careful replacement. Connections to commutator and to duplicate half must be broken before a bar can be removed.

In the case of a ring bar armature, of which type Crompton's dynamo presents a good example, both the exterior and interior bars must be taken out to permit of the re-installation of a complete "turn." In the case of a drum armature—the Edison-Hopkinson, for example—the complete "turn" consists of two exterior bars nearly opposite to each other upon the periphery of the armature. Fortunately, the bar armatures are not particularly liable to faults of insulation, but accidents will sometimes happen to the most carefully-insulated machine, and the material separating a pair of bars may be burned out entirely. The materials used for re-insulating bar armatures are chiefly vulcanised fibre and rubber, with varnished linen and tape.

In replacing bars care must be taken to insure that it is packed tightly; that the ventilating spaces of the armature are not choked up, and that it be effectually connected both to its other half and to the commutator segment representing it. Afterwards, the winding on of the exterior band is a matter of skill and thoroughness. As a rule, the bands are the chief protection against the casting-off effects of centrifugal force, and they must therefore be replaced as tightly as before. The great advantage of bar armatures bolted, instead of soldered together, is appreciated when repairs have to be carried out.

Removal of Wire Coil.—Wire-wound armatures cannot usually be tested while in position, if a coil requires to be replaced. The coil of a drum armature consists of two halves running parallel to the axis at opposite sides of the armature. The winding is carried over the ends, and it is therefore a complex matter to remove such a coil. It cannot be done, as a rule, without unwinding all the other coils, and a breakdown generally involves complete unwinding of the whole. For this reason wire-wound armatures for ship dynamos in foreign service should always be in duplicate, owing to the time required in rewinding, and the uncertainty of its being in the power of the regular attendant to accomplish the work.

Advantages of the Bar Armature.—Bar-armature dynamos are thus in every way better suited for ship-lighting than any other form. Wire-wound armatures are resorted to when a high potential is required. A high potential demands that the coils of the armature shall have a considerable number of turns, and this cannot be obtained in a bar armature. But the usual 55 or 105 volts necessary for incandescent lamps is not a high potential. It is easily evolved by an armature of few turns, moving at a slow rate of speed. Hence, it is safe to assume that wire armatures can be dispensed with for ship lighting.

Avoidance of Breakdowns of Dynamos.—In capable hands a dynamo seldom breaks down. A "burn out" of a coil or bar is due to a short-circuit by reason of which that bar does not yield its current to the working circuit. Its current continually circulates in itself until over-heating destroys the

insulation. This may be due, as before pointed out, to some defect in the commutator, or to some metallic contact between the ends of the coil. It is sometimes caused by a nail, screw, bit of iron, or a tool falling unobserved and lodging securely between two wires, between which there is a considerable potential difference. Or it may be due to a blow received by a bar or coil, by reason of which two portions intended to be separate are brought into contact. A general "burn out" of the armature may occur by any accident that causes a short-circuit in the mains. If this occurs beyond the main fuses the burning of these will protect the dynamo. But it is the practice to place the main fuses beyond the switch-board main connections—that is, on the main feeders themselves. There is thus considerable length of conductor between the dynamo terminals and the main fuses.

Any accident, as the falling of a metal bar across the mains from the dynamo to the switch-board, may thus cause a disastrous short-circuit. Hence, it is a by no means unnecessary precaution to establish a pair of master fuses at the terminals of the machine itself. If the latter be compound wound, its current will rise with every decrease of the external resistance, but a shunt dynamo may possibly be so well protected by its differential winding that burning may not readily occur. Hence, both series-wound dynamos, used in arc lighting, and compound machines, because they have series coils, are both liable to be destroyed by general short-circuiting.

These remarks are perhaps peculiarly applicable to the case of ship dynamos. These machines are frequently put in charge of functionaries known in the

engine-room as "greasers," or oilers, whose knowledge of a dynamo is often conspicuous by its entire absence, and therefore accidents of a serious nature are very liable to occur, but if the precautions above mentioned be observed, a bad "burn out" may be avoided.

Setting the Lead.—When the brushes of a dynamo are set upon the theoretical line, generally at right angles to the lines of magnetic force, there is apt to be a good deal of sparking at the brushes. Although this is, theoretically, the correct position for the brushes, yet dynamo-builders have not succeeded in employing materials that will enable their machines to collect upon the theoretical line. Hence, a certain amount of either backward or forward lead must be given to the brushes. The amount depends upon the speed of the machine and the current it is evolving.

In most cases *lead* is given by rocking the brushes in the direction of rotation. In some cases, as in electro-motors, it is given by rocking against the direction of rotation. When the dynamo has no load on, the brushes should—in machines with vertical magnets—be, respectively, exactly on the top, and exactly underneath the commutator. As the load of lamps increases, there will be sparking at the brushes. This indicates the necessity for lead. The lever carrying the brushes is capable of turning. Its set-screw is released, and it is turned slightly until the sparking disappears. In the case of compound machines, the greater part of the shifting will be required between no-load and half-load. Between half and full load very little shifting of the brushes is required. In the case of shunt machines, on the other hand, the shifting to full load is uniform with

the load—it coincides with the increase of lead. In series-wound dynamos, as used for arc-lighting, it is not usual to shift the brushes—the best position once found is always correct.

Taking off the Lead.—This is as important as giving lead. Suppose a dynamo at full load. It has as much lead as will insure the avoidance of sparking at the brushes. As the load of lamps is diminished, the sparking will increase, and the lead must be diminished. This goes on until there is no load and no sparking. A well-managed dynamo should start work with no lead in the brushes, and it should receive lead as required by the load. The best angle of lead is found by rocking the brushes a little too far, and then setting back until sparking is at a minimum. In shifting brushes care must be taken to avoid much sparking. In machines subject to a very variable load, the brushes are frequently set to an average position and left there.

Brushes.—These are subject to wear, and must be kept in a trimmed condition. The ends of brushes are usually filed in a brush block or clamp, so made as to indicate the correct angle of the ends. One angle cannot be made to apply to all machines. In filing brushes in a clamp the strokes of the file must not be against the leaves of the brush. A smooth file must be used, and the end trimmed must be flat and well finished. Emery is inadmissible. The very point of the brush should be slightly chamfered off. In the case of compound-wound dynamos the best thickness of brush is that which will touch, when bedded, upon one segment, one strip of insulation, and a quarter of another segment. In other words, the brush must cover one and a quarter segments.

One brush wears away faster than the other. This brush must be fed up from time to time to maintain its diametral position with respect to the other. The faces of the brushes must bed fairly along their width upon the commutator. If brushes be kept well trimmed and well bedded, and the angle of lead maintained correct, there will be very little wear of their ends. *The circuit should never be broken by lifting the brushes.* The result of breaking circuit in the commutator is to give a starting-point to a pair of burned spots, or "flats," which may cause almost endless after-trouble. Brushes must be fastened squarely and firmly in their brackets, and the latter kept scrupulously clean and free from copper dust.

Commutator.—The shaft of the dynamo should be allowed slight end-play. This promotes even wearing of the commutator, and prevents the formation of grooves. The surface should be kept quite clean, and only lubricated by the *slightest touch of vaseline.* Other oils must be avoided. Smoothness and hardness of the surface should be promoted by good treatment and well-trimmed brushes When rough, it is better to use a slip of fine glass-paper than emery in any form. The grains of emery once bedded in the copper continue to damage the brushes. A fine dead-smooth file may be occasionally used to smooth the commutator. Brushes should be kept off while smoothing or filing. Flats, or burned spots on the commutator, are due to the following causes:—

(1.) Lifting brushes while current is on.

(2.) Brushes out of position with respect to each other, caused by one brush wearing faster than the other.

(3.) Accumulations of oil and dirt upon the commutator, due to want of attention.

(4.) Periodical jar caused by direct driving-engine being out of repair; the jar causes extra sparking and burning at a given segment.

(5.) Armature electrically out of balance, a fault which causes extra sparking at a given segment.

Flats or spots are sometimes treated with the file, by filing down the adjacent segments slightly to allow the brushes to bear upon the flat. But a bad flat can only be removed by taking a cut off the whole surface of the commutator in the lathe.

Most large ships' dynamos are furnished with a *slide-rest*, which may be bolted to the bed, so that a cut may be taken off the commutator in *position*, in its own bearings. This is an excellent arrangement, and its practice should be general. A fine-pointed tool must be used in turning up a commutator; a round-nose tool will only drag the copper over the insulation. A light cut should be taken. The finishing should be done with a fine file. Examination is necessary thereafter to see that all insulating strips are clear of copper, and all turnings cleared away from connections to coils. Armatures removed from machines must be very carefully handled, and covered with canvas while in the lathe. The supports should be placed beneath the shaft only when the armature is laid down or lifted. See that all parts of the armature clear the lathe-saddle throughout traverse. Use a slow speed for turning, and a fast speed and long strokes for filing. Every care should be taken to maintain a perfectly round commutator, and a hard, glossy surface of contact for the brushes. This can only be accomplished by attention to every one of the foregoing hints, and general good treatment.

Pressure of Contact.—It is a great mistake to suppose

that the brushes should bear heavily upon the commutator. A touch sufficient to overcome the jarring effects of vibration while the main engines of the ship are in motion is all that is required. Pressure in excess of this only results in wear and tear of the commutator and brushes. If every attendant upon a dynamo would carefully note the tension of the brush-springs when the machine leaves the maker's hands, there would be less complaint as to wearing commutators. But pressure must be amply *sufficient*, otherwise jarring will cause loose contact and the formation of flats.

CHAPTER V.

HANDLING ELECTRIC SEARCH-LIGHT.

VERY large currents are generally used for search or navigating lights. From 50 to 100 ampères are frequently employed and still larger currents for naval purposes. The electro-motive force is commonly only 50 volts. There is no advantage in a higher pressure. It only requires a longer arc, which is easily proved to be less stable than a short arc. In the larger search-lights carbons as large as 2 ins. in diameter are frequently used. The candle-power varies, according to the current and pressure. The greatest current in common use is 100 ampères, yielding a light of about 30,000 candle-power. The smallest current is about 50 ampères, yielding about 15,000 candle-power.

A hand-lamp is generally used for search-light purposes, but there appears no good reason why an automatic lamp should not be made for this purpose. The work is rough, truly, and search-lights are subject to ill-usage, but, notwithstanding this, an automatic lamp of sufficient strength, and to work by means of a rack and train, might well be adapted for the work. So far, however, the Admiralty have only approved of a hand lamp of substantial pattern. Ships of the mercantile marine are also provided with a similar apparatus, and those in the Naval

Reserve are furnished with the Admiralty pattern of hand-lamp and projecting apparatus.

The hand-lamp (Fig. 13) consists of a substantial base, *a*, from which projects the attachments for the carbons and mirror. The main or back stem, *b b*, is placed at an angle of about 45° with the perpendicular. It consists of a planed square bar. Upon this bar slide the two carbon brackets, *c c*, top and bottom. Also the mirror, *d*, which occupies a central position, and which can be adjusted up or down by hand as required. The two carbon brackets are pierced with holes through the back projections, and these are screwed respectively with right and left-handed threads. A back-shaft, *e e*, screwed from the end to the middle with corresponding right and left-hand threads, passes through these projections from the brackets. This shaft, which is

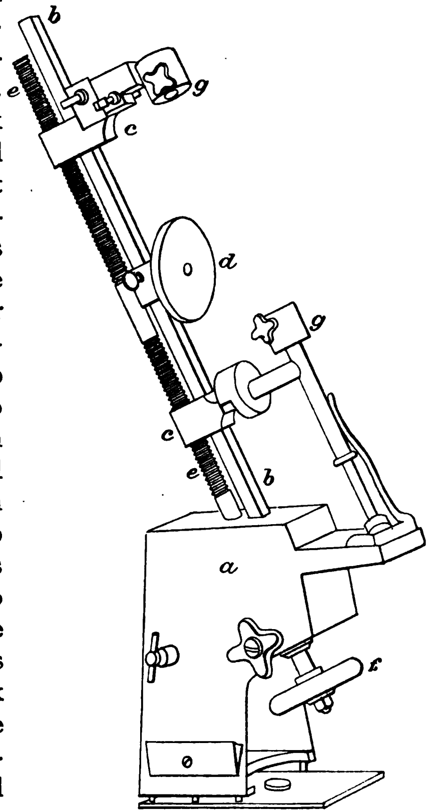


Fig. 13.—Admiralty Pattern Hand Lamp.

capable of rotation in suitable bearings, is furnished at its lower end with a hand-wheel, *f*, by means of which it may be rotated. It will be readily understood that when the hand-wheel is moved round the right and left screw either separate or bring together the carbon brackets, according to the direction of rotation. The brackets are provided with suitable circular bushings, *g g*, for receiving the carbon-rods, and these are fitted with screws for fitting the latter in position. The upper bracket is in electrical communication with the metallic slide and the screw, but the lower bracket is separated therefrom by an insulating arm. In order to give increased rigidity to the lower bracket it is furnished with a tubular stem, which slides upon a cylindrical rod, also projecting upwards from the base at the same angle as the main stem. A sliding contact is sometimes attached to this point. The insulation of the whole is effected by means of sheet asbestos faced with mica.

The dimensions of the Admiralty pattern lamp are:—height, 32½ inches; width of base, 10 inches; length, 15 inches; weight, without carbons, 31 lbs. This size is constructed to carry a current up to 100 ampères. When smaller carbons are to be burned than would be required for the above current, the carbon brackets are furnished with interchangeable bushings to secure centrality of the carbon-rods.

Manipulaton of the Arc.—The ends of the cables from the dynamo are first firmly secured in the binding screws of the lamp. In doing this sufficient insulation should be removed from the ends of the cables to allow of a length of two inches of the cable

being passed through each terminal. This secures them against partial slipping. The carbons being fixed centrally, they are brought together by means of the hand-wheel, and the arc thereupon set up is allowed to burn for a few seconds to assist in shaping the points. The hand-wheel is now gradually rotated until the carbons are separated the required distance to form a perfect arc. The arc is generally observed through a piece of smoked or coloured glass. The arc is lengthened until it begins to flare and burn blue.

At this point the adjustment is reversed, and the arc slightly shortened, so as to maintain as long an arc as possible without liability to flaring. When the arc is too short it produces a hissing and spluttering noise, and the light is enfeebled. The rate of consumption of the carbons, when they are of 40 mm. diameter, varies from 1½ inch per hour to 2 or 3 inches per hour, according to the current, the density of the carbon, the length of the arc, and other conditions. Smaller carbons waste away more rapidly.

In use the attendant must watch the arc and frequently bring the rods nearer together. Practically the adjustment should be continuous, because the consumption is continuous, but in any case care has to be exercised to provide against extinction of the light by too much or too little feeding.

Projector for Search and Navigating Light.—The projecting apparatus is intended to concentrate the light in a given path. It is made with and without lenses intended to give a diverging light. Reference to Fig. 14 will assist in elucidating its construction. The lantern is generally made of metal, jointed as

nearly watertight as possible, and of sufficient size to insure the glasses and mirror and lens against cracking, by reason of the heat from the arc. The inclined hand-lamp, just described, is placed within the lantern centrally, as shown. The front of the lantern carries a screen of brass rods to protect the glass against chance collisions. Within the metallic screen is usually placed a glass separator intended to protect the lens. The latter is represented in section. It is usually mounted in a flange of wood as shown, set in the metal frame of the lantern. This arrangement, especially if it be assisted by a packing of vulcanised rubber, protects the lens against objects striking the exterior of the lantern, especially with respect to concussion. Similar precautions are taken in the case of the mirror at the back of the lantern, which is usually made with a plane surface, intended merely to reflect the scattered light towards the front of the lantern. This mirror is generally protected by a clear glass screen, placed between it and the arc. The mirror proper, or convex reflector, is a part of much importance. It should be capable of throwing a parallel beam of light. Its light should be white, not yellow. Both the Scott and the Mangin mirrors claim to fulfil

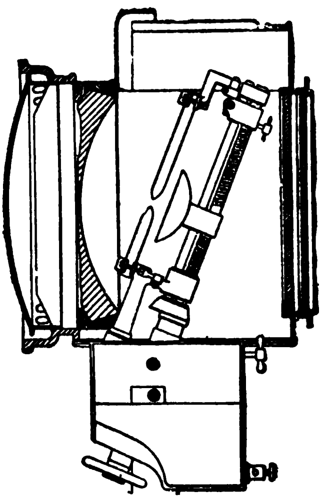


Fig. 14.—Suez Canal Projector, Section.

these requirements. The sides of the lanterns are provided with coloured observing glasses.

The lantern has three principal motions: 1, a motion in a horizontal plane to right and left; 2, an elevating motion, intended to throw the beam of light upwards; and, 3, a depressing motion, intended to throw the beam downwards. By a combination of these motions the beam of light may be thrown upon any distant object. The horizontal motion is either controlled by merely rotating the lantern upon its pivot, by hand, or by means of a worm and worm-wheel gear, controlled by a hand-wheel. The latter is usual in the first-class projectors of men-of-war. The elevating and depressing motions are controlled by a hand-wheel and worm-gear placed at the side of the lantern. In the case of navigating the Suez Canal the projector is placed in a cage, which is slung directly in front of the ship's bows, and close to the water. An attendant occupies the cage and operates the hand-lamp. Further particulars of the electrical connections for projectors are given further on.

Impedance and Choking Coils.—The electro-motive force of the dynamos used in the Royal Navy is very commonly 80 volts. Thus a very rare kind of incandescent lamp, taking nearly an ampère and a voltage of 80, is employed. This electro-motive force is too high for one arc lamp in series, and is not high enough for two such lamps in series. When the search-lights are on the circuit a special dynamo is generally used or reserved for them. It is a common, but not an invariable practice, to run two or more search-lights off the same machine, connected similarly to the incandescent lamps, in parallel. But the voltage being too high for an arc

lamp, some means of damming back 20 volts from the circuit of each lamp has to be employed, when upwards of 80 volts are given by the dynamo. The means generally resorted to for this purppose is an inpedance or choking coil. In many cases this consists merely of a simple resistance, either of iron or in some instances platinoid wire, or ribbon. The resistances generally mainly consist of spirals of iron wire, wound upon tubes of asbestos, which are in turn formed upon pieces of iron gas-piping. Open spirals are, however, more favourable to the dissipation of heat. The resistances employed vary in amount. A convenient resistance-frame for this purpose contains iron-wire coils having respectively a resistance of $\frac{1}{3}$, 1, $1\frac{1}{3}$, 2 and 3 ohms. The iron wire should be as thick as No. 14, S.W.G. Each coil has its own switch, so that any resistance can be inserted in the circuit.

In some cases these resistances are used as a shunt across from the lead to the return, but in that case must be of much greater magnitude—in other words the wire must be long and thin. The impedance coils are frequently formed around iron cores. The object of this is to check the great initial rush of current that takes place upon the closing of the circuit. The abnormal electro-motive force thus set up, when unopposed by the "back" electro-motive force of the arc, is very destructive to the mechanism of some arc lamps. In the case of hand lamps it is of less consequence. Impedance coils are kept in the dynamo-room, near to the switchboard, at the root of the main leading to the lamp. In some cases, however, they are placed close to the lamp itself, although this practice is better adapted

to the case of alternating current working, where arc lamps are run off the ordinary incandescent lamp wires. In this case the choking coil must accompany the lamp.

Handling of Arc Lamps.

The arc lamp performs but a small part in the interior lighting of ordinary ships of the mercantile marine. In the case of inland navigation, as in traversing the Suez Canal by night, the arc light is, however, indispensable. It is likewise used extensively as a cargo lamp for dock work and for coaling purposes. In the ships of the Royal Navy the arc system is necessarily an institution in itself. Here it is employed both for search and signalling purposes. Torpedo and other practice is also frequently conducted by night by the aid of the arc light. A few years ago the arc lamp, as a regulating mechanism, was so imperfect that the use of this kind of lighting was confined to special purposes. Employers of arc light abandoned it in favour of the more expensive incandescent lamp.

But there is at the present time no good reason for this. Of late the construction of arc regulating lamps has so far developed that several of the leading patterns may be regarded as near to perfection as we are likely to attain. When we add to this the fact that arc lighting is *exceedingly cheap* when compared with the incandescent light, it will explain why arcs

are coming rapidly to the front again, especially for the lighting of large spaces, where there is plenty of room overhead for the elevation of the lamps.

Different Systems of running Arcs.—Within a very few years back the arc light could not be subdivided. Every kind of attempt was made to work more than one lamp off one dynamo to little purpose. The electric "candles" of 1878 effected a partial solution of the difficulty, but the defect still lay in the arc lamp itself. The regulating mechanism therein was insufficient. There was only one solinoid or wire coil and this was placed in the main circuit. When the arc burned too long, and the light became weak, this solinoid withdrew its grip upon the upper carbon rod, which then suddenly dropped. The result was a partial extinction of the light and an immediate recovery, so much so that the arc now blazed forth in exaggerated splendour, only to fall off again in a short time.

The effect of this bad regulation upon the dynamo may be imagined. Since series-wound dynamos were used, a weakening of the current in the arc necessarily withdrew the power from the field magnet of the machine, and therefore the machine became weaker and weaker at the very time when it should have been the more highly excited. There was this balancing advantage that, as the current fell off, the dynamo was more easily driven, and the engine tended then to race (if it happened to be a *badly* governed engine), which, driving the dynamo faster, tended to augment the weakened current by raising the potential in the whole circuit. Thus even when one lamp was coupled to one dynamo the light was far from being steady. When two or more lights were placed upon one circuit the

result was still greater confusion, for every arc would be affected by the alterations in every other arc in the line. Hence it was considered impracticable to burn more than one arc from one dynamo.

Shunt Regulation of the Lamp.—By the addition to the arc lamp of a shunt regulating coil those defects were to a great extent overcome. In the older lamps the controlling coil, called the series solinoid, was merely in circuit with the lamp, and all the current passed through it. In the shunt regulating lamps the series coil is retained, but there is also a shunt coil connected as follows :—The shunt coil is of fine wire, the series coil being of heavy wire. When the current arrives at the lamp it has its choice of the coils. Both coils are connected to the terminal. It therefore divides itself between them in the inverse ratio of their resistances, the greater part of the current passing through the series coil and a smaller part through the finer shunt coils.

The latter thus forms a by-path to the series coil. The part of the current that passes through the shunt flows back to the main and so to the machine, while that passing through the series coil flows through the carbons and forms the arc. The series and shunt coils are frequently wound upon the same reel, and the currents in them flow in *opposite* directions. In some lamps, however, the shunt coil is separate from the series coil. In the former arrangement there is a single iron core, moving freely in the coils; in the latter arrangement there are cores, one for each solinoid, and they act upon opposite ends of a see-saw lever, each pulling against the other and tending to maintain a balance.

But the balance may be maintained within the

limits of a single solinoid, coiled in opposite directions with series and shunt wires, as already explained. The balance is kept up as follows :—When the current is turned on the carbons of the lamp are supposed to be in contact. There will thus occur a strong current in the series coil, preponderating greatly over that in the shunt coil, *because* the resistance of the main circuit is small when the carbons of the lamp are in contact. Therefore the series coil will exert a pull upwards, overpowering the feebler downward pull of the shunt coil. But the upward pull draws the carbons apart and establishes the arc.

The great resistance of the arc being now in the circuit, less current will pass in the series coil and a *larger proportion* of it in the shunt coil. The latter will, therefore, exert a still stronger downpull, and check the upward tendency of the pull exerted by the series coil, in this way *striking the arc* at its proper length. These conditions remain the same until the carbons burn away and the arc tends to become too long. The current in the series coil will thus begin to weaken. Its pull upon the core will relax, and as this implies increased resistance in the main circuit, a still larger proportion of the current will flow around the shunt. The strength of the latter will at this point preponderate over the strength of the series coil and there will occur a downward motion of the upper carbon. This again shortens the arc, and by diminishing the resistance increases the current, so restoring the balance.

Striking the arc is therefore effected by the series coil and *feeding* of the arc is controlled by the shunt coil. This system is known under the general name of the differential arc lamp system, since it is the

difference between the current in one coil and the current in the other that determines the regulation of the arc. Most of the best arc lamps are governed by the differential winding arrangement, although it assumes various forms in different makers' lamps. Allied to the single double-coil solinoid is the twin solinoid arrangement as found in the Brockie-Pell lamp, the Pilsen lamp, the Thomson-Houston lamp, and others. These generally act through a rocking lever, as before explained, the position of which varies, but its effect is the same throughout. In the Siemens differential lamp the shunt coil is separate from the series coil also, but placed co-axially with it, the iron core being continued through the centre of both.

Feeding is effected primarily by the counter-pull of the shunt, but between the core upon which it acts and the carbon-holder, there is usually placed some gripping or controlling device. Thus in Brush's well-known arc-lamp a tilting-ring is employed to grip the carbon-holder rod. The ring is tilted by a finger attached to the core passing into the solinoid. This arrangement is extremely simple, and very effective. There appears this defect in it, that the current is passed to the upper carbon by the tilting-ring as it touches the rod. This being the point of contact, the rod gradually becomes pitted or burned in spots by reason of numerous miniature arcs set up at this point. Such feeding-rods require to be kept very clean, and free from oil or other insulating lubricant.

Thomson and Houston also employ a similar gripping arrangement, acting directly upon the carbon-holder rod. In the Brockie lamp, a wheel and pinion, gearing into a rack in the carbon-holder rod,

are used. The wheel is pulled around little by little, by means of a friction-grip, under the control of the see-saw lever before mentioned. This arrangement is very effective, and overcomes the necessity to make contact through a clutch direct upon the rod.

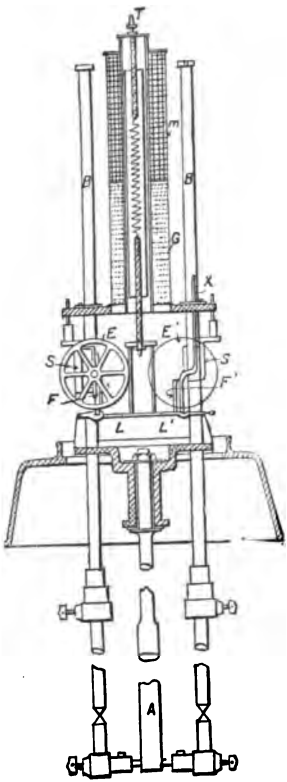


Fig. 15.—Compton-Crabbe Lamp, Section.

Detailed Description of a Differential Arc Lamp.—The Crompton-Crabbe lamp, a description of which is appended, is used extensively in ship work, and contains all the features of improvement mentioned above. It therefore forms a good example of the better kind of lamps. Its details will, if studied, serve to elucidate the principles of every kind of differential lamp used for ship work, while the old lamps, with single coil, had not the retractile power, the differential lamps are capable of either feeding or withdrawing the carbon. The lamp illustrated herewith controls two pairs of carbons, and is therefore adapted for running a great many hours, as a second pair is switched in after the first has burned out. Referring to Fig. 15, *B* and *B* are rack-rods carrying the positive carbons. Sliding on each of these is a light gun-metal sleeve, *S S*, carrying

spindles, to which are attached the two large brake-wheels, *E E*, and between them the pinion which gears into the racks. These brake-wheels rest upon a pair of levers, the outer ends of which are pivoted to the framework of the lamp, their inner ends being connected by links to the core of the solinoid, which is placed in a central position vertically above the two inner ends of the levers.

This solinoid is differential, *G* being the shunt, and *M* the main coil, and the core is partially supported by a spring, whose tension can be regulated by the screw *T*. This is the only adjustment required by the lamp for the regulation of the arc. The proper length of the latter is from $\frac{3}{32}$nds of an inch to $\frac{1}{8}$th of an inch. The screw *T* is turned to the right to increase its length, and to the left to decrease it. Projecting vertically downwards from the sleeves, and parallel with the rack-rods, is a stout pin or finger, *F F*, the action of which is as follows :—

The rack-rod is supposed to be drawn up; then if the lever be pulled by the solinoid above the horizontal position, the whole weight of the rod and carbon is supported on the edges of the two break-wheels, and the friction of them on the surface of the levers is sufficient to prevent their revolution; hence this rack-rod cannot run down. But if the levers be below the horizontal, then the weight is carried by the finger projecting from the sleeve, as shown at *F*. The wheels are free to turn, the rack runs down, and continues to do so until the positive and negative carbon points come in contact.

Now, let the current be switched on, by its passage through the main wire of the solinoid the levers are raised, striking the arc, and at the same time applying

the break to the wheels. The combined action of the shunt and main coils on the solinoid core automatically adjusts the length of the arc. If this becomes too great, the increased current through the shunt draws down the core and levers, the break-wheels are left free to revolve, and the arc shortens. On the other hand, if the carbon points be too close together, the levers are raised, bringing with them the rack-rod and upper carbons. The fact of making the finger projecting from one sleeve longer than the other, determines which pair of carbons shall begin to burn first, because, on switching on the current, that pair which has the longer pin will be the last to break contact, and will, therefore, originate an arc in so doing.

It will be obvious from Fig. 15, that, on the core being raised, the lever L' will apply the break before the lever L does. Hence it may be said that the rack-rod, B', gets a start on B; its carbon points are separated before those of B', and are therefore kept a greater distance apart until the latter are consumed. When this is the case, the rack-rod B is prevented from further fall by a stop, X, and can no longer feed. Hence the arc will lengthen, the shunt current will increase, and the other rod, B, which can still feed, will be allowed to descend until its carbons touch, starting a fresh arc. The core is raised again, the fresh arc burning instead of the old one, and everything goes on as before.

When fitted with the full length of 19½-inch carbon, 13 mm. in diameter, the lamps will burn from 12 to 18 hours, according to the current passing, which may vary from 20 to 8 ampères, the light varying from 4,000 to 1,000 candles, the light-giving

power being measured at an angle of 30° below the horizontal line cutting the arc itself. The electromotive force required is 45 to 50 volts. In Fig. 16, the connections of the lamp are still more clearly seen. The external case of the lamp is of cylindrical form, and attempts have lately been made to fit the cover to the interior so closely that neither dust nor damp might penetrate to the working parts.

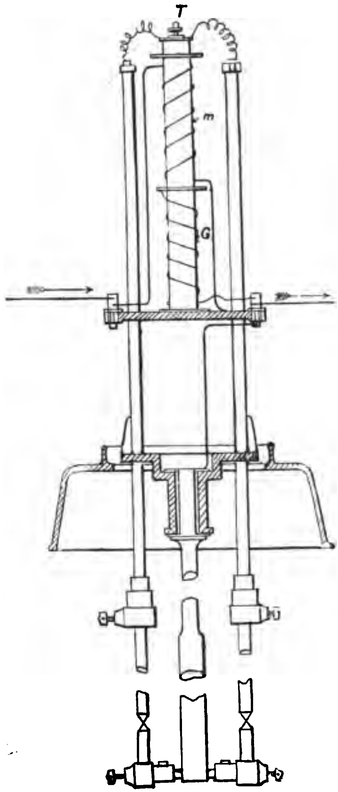


Fig. 16.—Crompton-Crabbe Lamp showing connections.

In the atmosphere of a dockyard, especially during coaling-time, the arc lamps are very liable to become clogged with particles of dust, and therefore call for frequent attention on the part of the cleaner. Dust-proof cases are therefore an obvious advantage, not only in dock but at sea, where arc lamps are liable to become ineffective by reason of moisture lodging in the interior. Still another advantage which makers of arc lamps are introducing at the present time is the complete insulation of the lamp case from both poles of the electric source.

In many forms of lamp it was the custom to make the body of the lamp act as one of the poles—generally as the "return." This had obvious disadvantages, inasmuch as it was very apt, by coming in contact with metallic articles, suspension-posts, or wire ropes, to form an earth fault, or to earth the return when that was particularly undesirable. In the case of currents of high tension the practice of including the lamp case in the circuit was decidedly dangerous to the attendants. In the lamp above described a plate of mica insulates the body of the lamp from all its attachments, and from its base.

Arc Lamp Trimming.—When an attendant does not thoroughly understand his lamps, there is likely to be trouble and unsteadiness of light. A few general rules, however, apply to all arc lamps. We select those that will prove useful in the case of arc lamps exposed to sea influences and to coal-dust and rain. The parts of the lamp most liable to become fast fixed or stiff are the sliding rods and racks carrying the carbons.

In some lamps both the upper and lower carbon-rods move. Such lamps maintain the light at one point, and may be regarded as focussing lamps. In this case the lower sliders are generally exposed to the air, and their freedom of movement must be maintained. It is usually a mistake to lubricate any sliding part of an arc lamp, more especially the upper carbon-holder rod. In carelessly-fitted lamps the sliding-rods are liable to stick fast after the lamp has become warm in working. There should always, therefore, be an allowance for expansion, but the sliding-guide must not permit appreciable side movement on the part of the carbon-rod, otherwise the

latter will not work steadily in line, co-axially, with its fellow.

Sliding parts must in no case be rubbed with any cutting powder such as emery. They should be merely wiped clean with a soft leather, and tested for freedom of motion. Most arc lamps contain within them a means of adjustment for working with weak or strong currents.

The electro-motive force is generally assumed to be from 40 to 50 volts. Arc lamps do not burn well with a smaller pressure, and a greater does not give a corresponding advantage. The length of the arc depends greatly upon the pressure. At full separation of the carbons the distance should not generally exceed $\frac{1}{8}$th inch when the current amounts to 10 ampères or over.

In the Crompton lamp the length of the arc is adjusted by imposing a more or less tension upon a spring. In the Brockie lamp the adjustment is maintained by adding or subtracting grains of shot from the balancing piston. Each lamp has its own method of adjustment. In a few arc lamps a dash-pot, containing a viscous substance, as a mixture of glycerine and water, is employed to cause the *gradual* descent of the upper carbon when it is released. This mixture must be kept at the proper consistency. In the Brush lamp, fitted with the glycerine dash-pot, the upper carbon-rod should fall the whole distance in the space of three minutes. If it falls more slowly the glycerine is too heavy, and water must be added. In a freezing atmosphere there may be a tendency of the glycerine to harden, and a little pure alcohol should be added to prevent freezing.

Inserting Fresh Carbon.—The carbons should be

of the proper diameter to suit the current to be passed through the lamp. Carbons 13 mm. in diameter may be burned by any current from 10 to 20 ampères. For heavier currents larger carbons are used. Thus a carbon 15 mm. in diameter may be employed in the case of any current varying from 15 to 25 ampères. In the case of small currents some lamps are capable of burning well with 6 ampères, and carbons corresponding to those currents must be employed. An unvarying rule cannot be given. Some carbons are much more dense than others, and therefore take a larger current to consume them.

In some arc lamps the upper carbons are larger than the under. This is intended to assist in maintaining the arc in one focus, but it is bad practice. In most lamps the upper carbon is longer than the under, because it burns away the faster.

Evidences of Excessive or Insufficient Current.—When the current is too great for the diameter of the carbon-rods, it is at once shown by the extremities of the latter becoming very hot to a considerable distance above and below the arc. A certain length of the rod will become red-hot, when the current is only sufficient to burn it freely, but this should not extend far from the arc. When carbons are too small, the overheating to which they are subjected greatly impairs their light-giving efficiency. When the current is too small for the size of the carbon, the extremities of the latter do not become sufficiently heated, and the whole of the rod is not included in the consumption by the arc.

The rods become irregularly shaped at the ends and are (the positive) deeply pitted, or have eccentric

points (the negative), as the case may be. The current and the diameter of the carbon should be nicely adjusted to suit each other.

Direction of the Current in the Arc.—The direction in which the light of the electric arc is thrown greatly depends upon the position of the carbon points between which it plays. The positive point, or that from which the current flows, becomes hollowed out, while the negative becomes pointed. In a lamp to be hung overhead the arc will be projected downwards if the upper carbon be the positive, as is usually the case. If the under carbon be positive the arc will become diffused upwards. This peculiarity of the arc is frequently taken advantage of in both projector and lighthouse lamps. In the latter case it is usually desirable to throw the light upwards, aided by the lenses of the lantern.

In the case of ordinary lighting the positive wire from the machine should invariably be connected to the terminal of the lamp communicating with the upper carbon. If there should be any doubt as to which is the positive lead, as in the case of the machine being at a distance, it can soon be ascertained by allowing the arc to burn for a few moments.

Variable Arc—Unsteady Light—"Pumping."—When an arc varies much at short and irregular intervals, and the lamp is a shunt-wound one, the fault is not generally in the engine, or in the dynamo, or circuit, but in the lamp itself. It points either to bad carbons, or to some defect in the feeding arrangement of the lamp. In the case of balanced lamps the sliding rods may not move freely. In the case of a lamp with a clutch, wheel and pinion, it may be due to irregular

action upon the clutch, which may be partially slipping upon the flange of the wheel. In more cases it is due to faulty connections or contacts, especially in lamps making connection with the carbon-holder rod by the aid of the tilting ring, now so well known. Regular fluctuations of the light, especially if rapid, are known as "pumping," and are generally due to an unsteady output of the dynamo, the commutator of which may be faulty, or the driving may be irregular. Faults in the line usually result in dimming of the light, due to leakage from the lead to the return, or from the former to earth. Intermittent dimming may be due to the lead or return being swayed by the wind against some metallic or wet contact, so establishing a momentary short circuit, or the lamp itself may be in motion and its action disturbed by the same cause.

Faulty Arc.—The arc may be made too long for the electro-motive force and current. An unsteady arc, which is not due to any of the above causes, is almost certain to be too long. At this time it presents a very blue appearance, and has a flaring look. The length of the arc should be adjusted until it has a firm, steady appearance.

Hissing of the Arc is almost invariably caused by the separation of the carbons being too small. It indicates an abnormally high temperature of the arc. Notwithstanding this, too short an arc emits but a feeble light, chiefly because the arc is partially shrouded by the edges of the positive carbon. A greater separation of the points should be made by the means of adjustment provided on the lamp. But hissing may be caused by the current being too great for the size of carbons in use. Coppered carbons

are sometimes troublesome in this respect. These carbons emit an arc having a greenish tint, and are better adapted for outdoor than internal lighting. Frying or hissing is in some cases due to bad carbons. When a lamp is first started the light is neither so good nor so steady as it will ultimately become. This is due to the faulty shape of the points at starting. An arc will not burn well in a draughty place.

Handling of the Thomson-Houston Arc Lamp.—A great many of these being in use in connection with cargo work, it may prove useful to offer a few hints as to their treatment, since they are rather different from English lamps.

Tension of the Rods.—This is adjusted by raising or lowering the arm at the top of the guide-rod, thus increasing or diminishing the tension of the clamp spring. If the tension is too tight the rod and clutch will wear badly, the feeding will be uneven, causing unsteadiness in the lights. Too weak tension will not allow the clutch to hold up the rod, and any sudden jar to the lamp will cause the rod to fall and the light will be extinguished. The double lamp should have the tension of the second carbon rod a trifle lighter than on the first one. When adjusting the tension care should be taken to keep the guide-rod perpendicular, and to insure that it is in perfect line with the carbon rod. It should be free to move up and down without any tendency to stick. The tension of the clutch in the *D* lamp should be the same as of the *K* lamp, and is adjusted by tightening or loosening the small coil spring from the arm of the clutch to the bottom of clamp stop.

To adjust the Feeding-Point.—Depress the main

armature as far as it will go. Then push up the rod about one-half its length. Release the armature and then press it down slowly and note the position of the lower side of armature above the base of the curved part of the pole. When the rod just feeds this should be one-fourth of an inch. If this distance is not secured, raise or lower the small top which slides on the guide-rod passing through the arm of the clutch, until the carbon rod will feed when the bottom of the armature is one-fourth inch from the pole. To adjust the double lamp the above will indicate what should be done with regard to the first rod. After this has been done let the first rod down until the cap at the top rests on the transfer lever. The second rod should feed with the armature at a point one sixteenth inch higher than it was while feeding the first rod, that is it should be five-sixteenths inch from the base of the pole. In the *D* lamp the feeding-point is adjusted by sliding the clamp stop up and down so that the rod will feed when the relative distance of the armature of the lifting and the armature of the shunt magnets from rocker frame are in the ratio 2 to 1. There should be a slight play in the rocker between the legs of the rocker frame.

General Examination.—Make a careful examination of all joints, screws, wires and connections of the lamps. The armatures of all magnets should be central with the cores and come down to them squarely and surely. There should not be a separation of one thirty-second inch between the silver contact when the armature of the starting magnet is down. The contact should be square when the armature is raised. The arm for adjusting the tension should not touch the wire or frame of the lamp when at the highest

point. There should be a space of three thirty-seconds inch or one-eighth inch between the body of the clutch and its arm. This is to allow for wear of its bearing surfaces. Trim the lamps with carbons of the proper length to cut out automatically, that is, there should be twice as much projecting from the top as from the bottom holders.

Allow a space of one-fourth inch from the round-headed screw in the rod near the upper carbon-holder to the edge of the upper bushing when the switch is turned off to allow sufficient space to start the arc. Accurate centring of the carbons is very desirable. The rods should be slowly rotated into their holders until a co-axial position is found; they should then be firmly clamped. The arcs of the 1,200 c.p. lamps should be adjusted to three sixty-fourths inch with full length of carbon. Arcs of the 2,000 c.p. lamps should be adjusted from one-sixteenth inch to three thirty-seconds inch when good carbons are used. Lamps should always maintain a fairly even arc. Its length will slightly increase as the carbons burn away, but the arc should not flame, hiss, nor the lamp over-feed at any time.

If the switch is opened and the lamp thus thrown out of circuit and then quickly thrown into circuit again, the top carbon should "pick up" promptly with normal arc and not hiss longer than a few seconds and then burn as quietly as before. When again tested by drawing the top carbon up by hand the lamp should cut out promptly and not "flash" the dynamo. In case the arc is very long and causes flashing examine the contacts and see that they are clean, and make effective, square connection. Examine also the centring of the armature. The action of a bad feeding

lamp may be confounded with that of a bad flaming carbon. This can be readily distinguished after a few minutes' observation. The arc of a bad feeding lamp will generally grow long until it flames, the clutch will release its hold suddenly, the top carbon will fall until it touches the under carbon, and then again pick up. A bad carbon may burn nicely and feed evenly until a faulty spot in the carbon is reached, when the arc will suddenly become long, and flame and smoke due to impurities in the carbon. Instead of dropping, as in the above supposed case, the top carbon should fall to its correct position without touching its fellow below.

Personal Precaution.—When several arc lamps are run upon the same circuit they are almost invariably in series, and therefore the electro-motive force is equal to the number of lamps multiplied by some figure between 40 and 50. Hence, when even five such lamps are in series the pressure is sufficient to disable the attendant if he be not warned. There is only one safe rule, and it is to never handle an arc lamp until after it has been switched out of circuit.

Automatic Cut-out.—When several arc lamps are run in series, a fault in one of them might serve to break the circuit, and all the others might be extinguished. But the automatic cutting-out device now applied to all lamps obviates this difficulty. It is generally of an electrical nature. It usually consists of a small auxiliary electro-magnet, connected as a shunt in such manner that when the current through the arc fails from any cause, as the burning out of the carbon rods, the whole current passes through it. The armature attached thereto is then pulled over and serves to put the lamp out of the circuit by means of an indepen-

dent pair of contacts. The main current thus passes the lamp, without entering the coils, and the general circuit is not disturbed. When lamps are arranged to cut out in this way the dynamo is liable to be disturbed by sudden falls in the resistance of the circuit, and should be furnished with a compensator.

CHAPTER VI.

WIRING AND FITTING OF SHIPS.

Complex Requirements of Ship-Lighting.—The furnishing of electric light to a large modern theatre has been considered by experts as a matter demanding for its successful accomplishment a great deal of thought and care. But it has been well said that even this task is simple compared with the successful wiring and fitting of a liner of the mercantile marine or a man-of-war. In the former case the course of the wires is at least not subject at any time to be under water or surrounded with moisture; all is dry, and likely to remain so. Therefore the chief attention is bestowed upon the proper distribution of the lights and their efficient regulation, with precautions against breakdowns in the dynamo-room or upon the circuits. But in the case of a ship the conditions are very much less favourable, and even more complex. A modern ship consists of a great number of separate compartments, made water-proof by means of longitudinal and transverse bulk-heads. These extraordinary precautions are taken to obviate the danger of sinking in case of accident as from collision or torpedoes or other projectiles.

Provision against Effects of Collisions, &c.—In considering the scheme of lighting the possible con

tingency of one or more of the watertight compartments being full of water has to be considered. It is not only necessary to provide for the lighting of each division of the vessel, from the deck to the bilge, but such precautions must be taken as will be likely to insure against the extinction of the light in any other part of the ship in the event of a particular compartment being flooded.

It may be contended that this contingency, in the case of vessels of the mercantile marine, is sufficiently remote to render such precautions unnecessary. But, although there may be some reason in this, yet it should be remembered that collisions are of daily occurrence, and that they most frequently occur during the hours of darkness.

If, therefore, we consider that such an accident is likely to extinguish all the lights, and total darkness follows an alarming crash, the effects amongst a mixed crowd of passengers are sufficiently obvious to impel shipowners to arrange at least for a continuance of light in the event of even a great disaster.

Chances of Fire at Sea.—But the possible flooding of compartments with water are not the only things to be considered in ship wiring. Vessels of the merchant service and war-vessels also carry at times large quantities of combustibles. The former carry very frequently that most dangerous kind of cargo, cotton, filling hold after hold. The latter carry stores fore and aft, fitted with various fire-raising materials and explosives.

But the merchant service are much more liable to suffer from fire at sea than the ships of the regular navy. It must not be supposed that passenger vessels, even of the first class, can afford to refuse

cargo of a combustible nature. Indeed their load is generally of this kind, and cotton is very commonly carried. Spontaneous combustion of cotton is now so well recognised that at no time is a vessel carrying it strictly free from the risk of an outbreak of fire.

Hence it will be seen that fire in a compartment is a greater enemy to the electrician than water. If his main cables pass through the compartment flooded or containing fire, he may expect at any moment total extinction of all lights. He has again to consider that fire is liable to destroy deck-houses and other erections through which his cables may pass.

Difficulties due to Water, Damp, and Moisture generally.—While the lighting of a dwelling ashore at least provides a course for the wires which is dry, and likely to remain so, the same advantages do not obtain aboard a ship. Moisture in any form is a great enemy to effective insulation. It may arise from water—sea-water—flooding the course of the wires and soaking their casings. Or it more frequently arises from "sweating" of the whole interior shell of the ship. In this latter case "sweat" will condense upon every surface it is desirable to keep dry, and leakage of current is inevitable.

But both the sousing with salt water and the general damp cause after-trouble, inasmuch as the wet sooner or later obtains access to the wires and gives rise to short-circuits and leakage. There is thus frequent danger from fire arising from over-heated electrical wires, a danger which fuses and cut-outs are sometimes powerless to avert. It is not to be forgotten also that salt is a deliquescent substance, absorbing moisture from the atmosphere, so

that circuit paths once soaked with sea-water are liable to remain in a moist condition for some time thereafter.

We have to add to these unfavourable conditions the fact that most steamships, especially passenger-vessels, are permeated with steam and water-pipes. They run in all directions, below and above decks, and it is impossible for the electrician to avoid crossing and running parallel to them with his cables. The water-pipes are damp, and the steam-pipes are hot. The former causes faults by moisture, and the latter burns up or deteriorates the insulating material covering his wires, and cracks and loosens their casings.

These Difficulties augmented by "Ship Return."— In the case of a ship being wired throughout with twin wires, the above sources of trouble are sufficiently annoying, but when, as is usually the case, the installation is worked through a lead and a ship return, that is, when the return current is practically earthed, they assume undue proportions, and call for much forethought and the best of work in laying the wires and fittings.

Distribution of the Lights not easily accomplished.— A ship is different in one respect from an ordinary building. Everything is on a smaller scale; height and width of rooms and passages have to be sacrificed to necessity. Even the grand saloons of ocean liners must be made with a low roof. These conditions render the effective lighting a matter of no common difficulty. Overhead lighting is well known to be the most effective, but it is seldom that it can be applied aboard ship.

The height of the eye is a very ineffective and

unpleasant position for a bright lamp, but this height is generally the restricting position for lamps, especially below the main deck. The lamps may be placed overhead in some cases, but their height then does not much improve the illumination. Considerable ingenuity has therefore to be exercised to so place the lamps that they shall be out of the way of injury, that they shall not offend the eye by being upon the same level, and that they shall prove effective in lighting the space required. It is seldom that lamps can be placed in passages overhead, owing to the liability to breakage there, and side-lighting of passages is obviously ineffective. Strong end-lights in passages are effective, but they cannot, in many cases, be used.

From these considerations it will be clear that in ship-lighting a much larger number of lamps must be employed than would be necessary were it possible in all cases to take the light all around each lamp. Bulkhead lamps, it is true, are frequently made to do double duty by lighting both sides of the division, but in most cases, when the bulkhead is a water-tight one, this is not permissible. Passage lamps can only frequently give light from one side, and so on.

Position, &c., of Dynamos.—The position assigned to the dynamo is a matter discussed at some length in Chapter I. It may be pointed out here, however, that the chances of a particular compartment becoming partly filled with water should not be absent from the mind of the shipbuilder in assigning a place for the electric machinery. That it should be placed high above the ship's bottom, there can be no doubt. The case of war-ships is, however, somewhat different; the vital parts are, in such in-

stances, placed below the water-line, or protected by armour.

Switch-Boards.—When a ship carries three or more dynamos, the switch-board becomes an important part of the installation. What is really required in a switch-board cannot be foretold until two matters have been settled: these are, the number of dynamos to be used, and the method of their use, and secondly, the number of circuits to be run in the ship. The primary requirement of the switch-board is that it shall enable the engineer to put all or any of the circuits on to any single dynamo, or on to more than one dynamo. In this way the load may be thrown on to one machine, or may be distributed between them, as the case may require.

In addition to this, the contacts or breaks at the board must be positive and effective, and not liable to be burned by arcs established upon breaking the circuit. Still, in addition, the board should carry a set of cut-outs or safety-fuses, one to each circuit, as it leaves the board. The switch-board is generally in duplicate, but the positive or lead switch-board is the more important. There must, however, be means of disconnecting the negative wires of the dynamo from the returns, or from "earth," as the case may be, as well as the positive or leading terminals. This is not commonly done when work is contracted for and carried out carelessly at a low price, but it is a precaution that no prudent electrician would care to ignore. Hence, not only should the positive board carry a full set of fuses, but the negative board also. If the ship be wired with double cable throughout, the necessity for the negative board becomes imperative.

Fuse boxes are, however, very often disconnected

from the main switch-board, especially the positive, and form a separate frame. The object for separation is to assist in simplifying the switch-board itself. But such precautions frequently lead to a multiplicity of short lengths of cable and extra connections, so that on the whole it is generally considered better to mass the whole of the terminal requirements upon a board where the full set may be seen at one view. When a fuse at the base of a circuit burns out, and it is desired to replace it immediately, this cannot commonly be done under a loss of time of several minutes. There is generally a delay in finding a spanner or a new fuse, which leads to the lamps upon that circuit being unlighted for some little while.

Recently there have been brought out fuse arrangements possessing double cut-outs for each positive terminal. Only one of these is in use at a time. When one of them goes out, a plug is withdrawn or inserted, which instantly puts the other fuse on to that circuit, and the attendant may replace the burned one at leisure. This plan is convenient where there is only one dynamo, or where there are several dynamos but all of them engaged upon some other circuit. Where there is kept a spare dynamo, with a full set of spare connections, ready for switching into any circuit, the double system may be dispensed with.

Typical Switch-board.—Fig. 17 represents the kind of switch-board used in the ships of the English navy. It is arranged to carry the cut-outs and the opening and closing levers. The particular board represented is for the positive side of the dynamos. The terminals and arrangements are intended for three dynamos, working six circuits. The connection blocks 1, 2, and

3, receive the cables from the positive terminals of the dynamos, the ends being secured by the hexagon-headed bolts. The connectors 1, 2, &c., to 6, represent the six circuits. Any one of these connections, or a

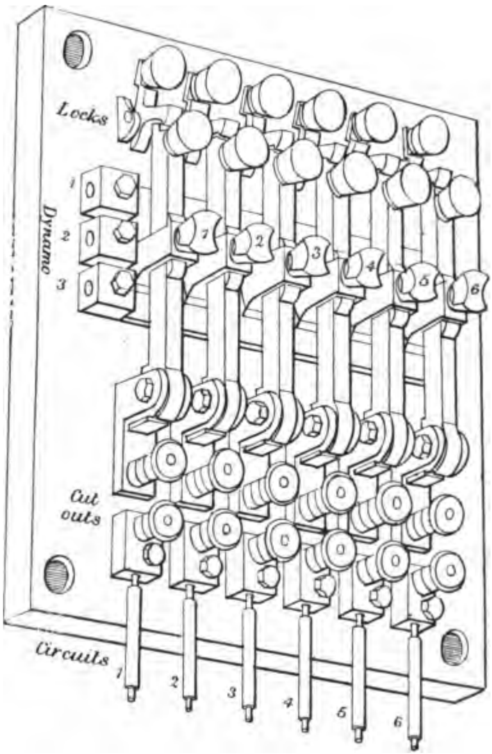


Fig. 17.—Admiralty Pattern Positive Switch-board.

number of them, may be put in contact with the positive lead from any one dynamo. Any required connection can easily be made at this point; there being six connectors and three bars representing the dynamos,

eighteen changes may be made. The six heavy vertical connection bars are provided with ebonite handles at their upper ends. They are held and locked in position when once set by the spring snap catches shown.

The vertical bars are hinged at their lower ends. The hinge blocks are continued downwards and carry the upper ends of the fusible slips; these are secured by means of the thumb nuts. Still another set of six connections at the lower end of the board receive the free ends of the fusible slips, and also carry the commencing extremities of the six circuits. These are inserted in the sockets and secured by means of the hexagon-headed screws. The whole of these arrangements are usually made in a good quality of gun-metal; they are mounted upon a slab of hard slate, and to prevent the possibility of the creeping of moisture beneath the connections, layers of mica are frequently interposed. In this particular form of switch-board all the connections are brought into view at the front of the arrangement. This method of construction has certain advantages in the case of ship-lighting, especially when there is a risk of damp finding its way behind the board.

Any defect in the contacts can be seen and rectified at once, without disturbing the fastenings of the board; to a trained electrician no doubt this style of fitting is the best of all, but there are many ships furnished with switch-boards in which none of the connections appear at the front. The only contacts there are the circuit closers, and possibly the fuses also. All connections from the terminals of the dynamo to the board and from the board to the beginning extremities of the leading wires are effected at the back.

However neat this arrangement may appear, it is impossible not to feel that it is unsuitable in the case of most ships. No doubt a board carrying a number of cable connections, which might be hidden from view, presents a complex appearance, and may even be held to confuse an inexperienced person; but the obvious advantage of having everything ex-

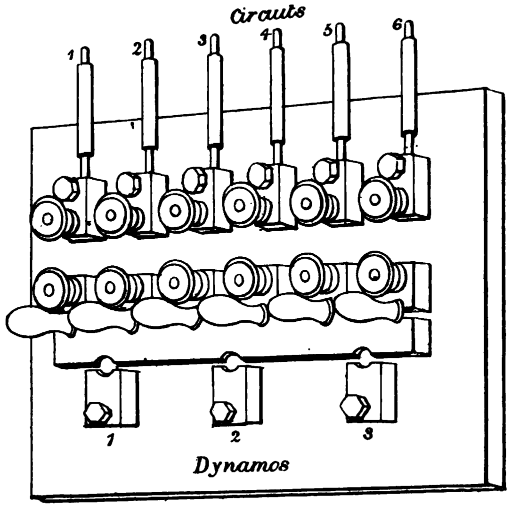


Fig. 18.—Admiralty Pattern Negative Switch-board.

posed to view, and especially available in case of the necessity for alteration or searching for faults, impresses us strongly in favour of the open board.

Negative Switch-board.—A view of the negative switch-board used in the English navy is given in Fig. 18. It consists of an incombustible base, upon which are mounted, at the upper end, the connection blocks 1, 2 and 3. These receive the ends of pieces

of cable, taken from the negative terminals of the respective dynamos.

Immediately beneath the three connections runs a transverse gun-metal bar. There is a space between the connection blocks and the bar sufficient to prevent the occurrence of an arc under an electro-motive force of 100 volts or over. Connection between the blocks 1, 2, and 3, and the bar, is made by the insertion of the metallic plugs represented. These are furnished with insulating handles, and the ends of the plugs carry locking pins, so that when a plug is placed in a hole and partially turned, it cannot by any accident or jar fall out. Beneath the bar are ranged six fuse blocks, which may be connected with it by means of plugs similar to the above. Still another set of fuse blocks, having connection screws for the extremities of the six return wires, completes the arrangement. The fuse slips are secured down to the blocks by means of the thumb nuts shown.

It will be observed that any or all of the dynamos may be connected to any or all of the return wires. Both in the positive and negative boards it is possible to replace a fuse in about a minute of time, without having recourse to the use of wrenches or spanners.

Double-Pole Twin-Fuse Switches.—The arrangements specified in the Admiralty style of switch illustrated above are specially adapted to the case of ships carrying two or more dynamos. Many vessels carry four or five dynamos, but the switchboards required need not vary in design from the Admiralty pattern. They need only carry additional levers and connections for the additional machines. The circular or rotary pattern of switch is apparently going out of fashion. It consists of a central lever,

connected to the positive or negative terminal of a dynamo, capable of moving in an arc, and making contact with two or more circuits, or of opening and closing a circuit as required. The difficulty experienced in the use of this kind of switch is that of obtaining good connection and of avoiding arcs when the circuit is broken. Complete disconnection of both the terminals of the dynamo from the circuit it feeds is frequently a very desirable condition, especially when the ship is wired on the double system. In addition to this the inductive capacity of long circuits appears to store up a considerable electro-motive force. The result is observed when such a circuit is suddenly severed. There is a considerable back rush of current across the gap, resulting in a flash and partial fusing of the contacts.

This spark is very destructive to the contacts, and may even, in imperfect switches, set up an arc resulting in the burning of the switch. The spark cannot easily be got rid of, but it may be divided, so that it loses its energy considerably thereby. This division is accomplished by means of a switch so arranged that the break of circuit is double, called a *double-break* switch. The switch itself may be duplicated, so that it severs both poles of the dynamo from both the leading and the return wires of the circuit. This class of switch is known as a *double-pole* switch.

It is seldom that both of these conveniences are to be found in a single switch, but in a particular pattern brought out by Westinghouse the two are combined in a very efficient manner. Still, in addition to this, the switch carries not only a pair of fuses, called a *double-pole cut-out*, but these are duplicated, or act as twin cut-outs. The convenience of this will

be obvious to engineers who have experienced the annoyance of seeing the fuse "blow" through a slight accident, and so extinguishing every light upon a circuit. In the ordinary course the fuse cannot be replaced in less than a minute or two, and not in that time if the dynamo-room happens to be lighted from that circuit, and is thus itself in darkness.

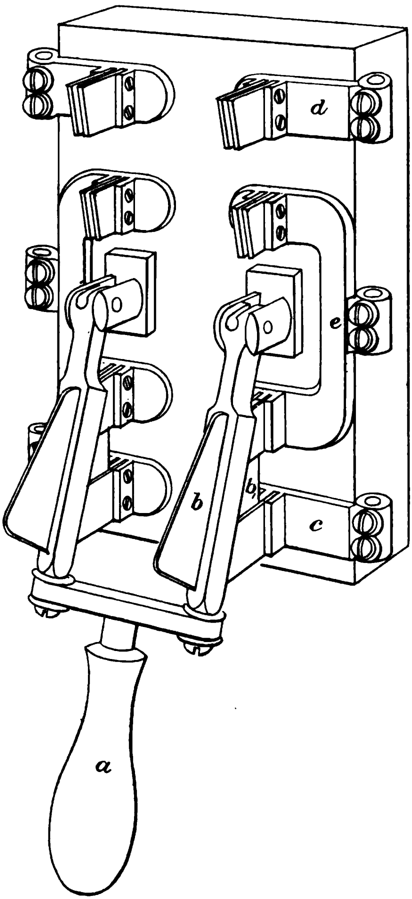


Fig. 19.—Westinghouse Change-over Switch.

Dynamo-changing Switch.—In most installations of electric light aboard ship some arrangement is made to insure against total extinction of the lights. This is more especially the case in passenger vessels. Some of the best of these carry a complete duplicate plant, others carry a partial duplication. Thus, where three dynamos suffice to light all of the lamps, the ship will carry a fourth machine, which is always kept in reserve.

We will suppose a simple case, in which the vessel carries two dynamos only, working on to one pair of mains. In this case it is unnecessary to provide complex switching arrangements. All that is required is a double-pole double-break switch capable of placing either dynamo in connection with the mains, as may be required, and at the same time cutting off the faulty machine.

In Fig. 19 is represented a change-over switch of this kind, introduced by Westinghouse. It is without fuses. The lever *a* carries two pairs of knife-blade contacts, *d d'*. If the first dynamo have its poles connected with the lower terminals, *c*, the switch will transfer its current to the central terminals, *e*, connected with the lamp circuit. If the second dynamo be connected with the upper terminals, *d*, a throw of the switch, bringing lever *a* to the top, will cut off both poles of the first dynamo, and put the second dynamo in connection with the lamp circuit at *e*. The switch may, however, be used for the complete double-pole disconnection of both dynamos from the lamp circuit by placing the lever *a* in an intermediate position.

Single-Pole Single-Fuse Switch.—In many cases only a single dynamo is carried, and the vessel is wired for ship return, or the negative or positive pole of the dynamo is earthed. In such instances a single switch is sometimes considered sufficient for the simple requirements of the lighting. The pattern represented in Fig. 20 will be seen to contain all the elements of such a switch. It is furnished with double-break arrangements. The lever *a*, which is jointed at *b*, carries a knife-blade connector, which makes contact at *c* and *e*. The cut-out is inserted at

d. The positive or negative pole of the dynamo, as the case may be, is connected to *e*, and the extremity of the leading wire of the lamp circuit is connected at *f*. When the lever is raised clear of the contacts, it is held in that position by means of a spring and catch in the joint piece, *b*.

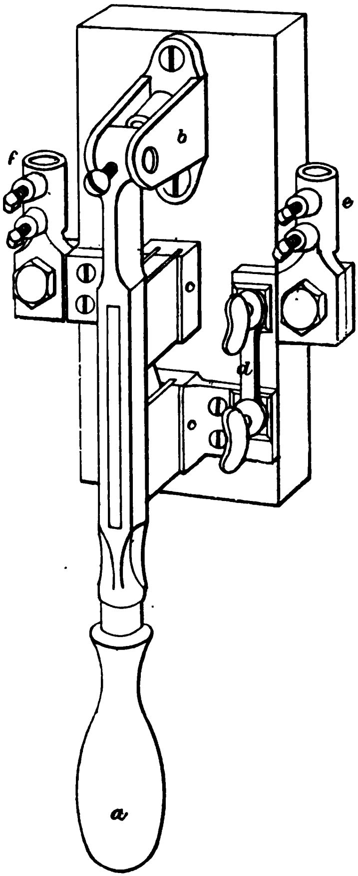


Fig. 20.—Double-break Switch and Cut-out.

Single Switch for main Current.—In the case of small installations single-break switches are considered sufficient. They are also extensively used for sub or branch circuits. In some instances the switch base carries also a cut-out, but this is the exception rather than the rule. Fig. 21 represents the Ediswan chopper pattern of switch, capable of carrying currents up to one hundred ampères. It consists of an insulating lever, jointed upon blocks attached to an enamelled slate base. The handle, *a*, is placed at an angle of 60 degs. to allow of a good purchase in taking off and putting on the switch.

The horizontal bar, of gun-metal, terminates in a double spring contact, *b b*, which, when forced between the pair of jaws *c c*, connects them across metallically. The contact obtained in this way is very good, and the spring fork being subdivided by means of saw-cuts, a large surface bears upon each terminal. The current does not in this case pass through the joint of the lever; it merely passes from terminal to terminal through the contact fork. The connections of the dynamo and the lamp circuit are effected at the back of the switch at *d d*.

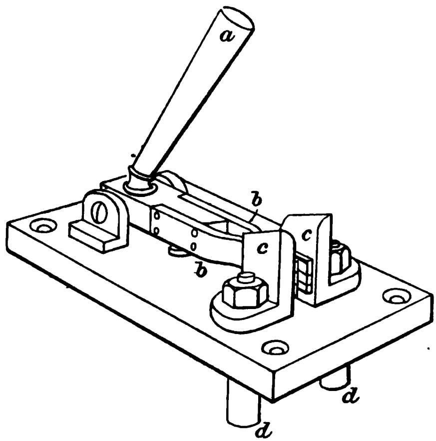


Fig. 21.—Double-break Chopper Switch.

Single-Pole Fuse Case.—Main fuses and cut-outs are variously arranged. Many engineers prefer to place them at the base of the circuits leading through the lamps, and therefore entirely disconnected from the switches or distributing arrangements. Some persons exercise so much caution as to duplicate all main fuses upon the same lead. This is questionable practice. It is quite different from providing double-pole fuses, a very necessary precaution. Duplicate cut-outs introduce faults of connection, multiply bad contacts, and are in every way a source of trouble without apparent advantage. It is a very usual practice to bring the base of each

lamp circuit to a fuse-board or box, containing a sufficient number of connections. One of these cases is represented in Fig. 22. It consists of a slate base or back, *a*, to the face of which are fitted two rows of connections, *b*, six in each. The connections are furnished with binding screws, to which are attached the wires from the switch-board or dynamo upon one side and the commencing ends, or roots of the lamp circuits, *d*, upon the other. These connections carry each a peculiar form of spring clip, which is faithfully represented in the engraving. The fuses themselves, *c*, consisting of slips of a tin-lead alloy, have blades of copper extending from their ends, which are easily slipped into position between the ends ot the spring clips. Six of the fuses are shown in place in the figure. The whole is surrounded by a teak-wood case, having a glass front. This form of fuse-board may be used either to feed six circuits from one pole of the dynamo, or six circuits from as many different dynamos, according as to whether the upper contact bar is continuous or subdivided. The board represented is intended to protect six circuits operated by one dynamo.

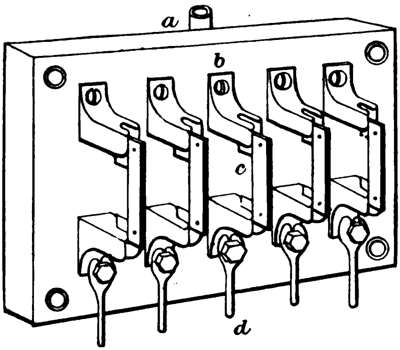


Fig. 22.—Multiple Fuse Box for Branches.

Charge and Discharge Switch for Accumulators.— When electricity is stored for use when the dynamo is stopped, a special form of switch is of much service

in enabling the attendant to supply the battery at the required number of volts.

In installations, where the engine is run during the heaviest part of the lighting, the batteries being employed as regulators, it is essential to be able to charge the "extra cells" ready for use after the engine stops, which can be done by moving the charging side of the switch until it is connected with the whole battery, the lamp connections being varied until the required pressure is obtained. When variations of pressure are very great each contact may be connected so that it represents two or more cells being thrown in or out. One very important essential is provided for in this form of switch, the movement of the lever from one contact to the other is so rapid that the current is not perceptibly interrupted, but, nevertheless, no short-circuit of the cells takes place.

Short-circuiting Plug.—The short-circuiting plug, Fig. 23, is connected across any instrument or apparatus which it may be desirable to cut out of the circuit at any time for repair or adjustment. Thus, voltmeters are not generally kept permanently in circuit, and a means of readily cutting such indicators in or out is indispensable. The wires are connected directly through the side receivers, and when the plug is withdrawn the current flows through them. The insertion of the plug, however, offers a short passage for the current through the block, and thereby cuts out the connected apparatus, enabling it to be removed without interruption to the service.

Lightning Arrester.—It is not often that the electrical plant in a ship is disturbed by lightning, but such an occurrence may take place in a wooden vessel

or in connection with parts of circuits necessarily run up masts and along spars, or in dock when overhead lighting is going on. Lightning frequently enters lighting circuits ashore, and sometimes destroys the instruments, and even burns up the armature of the dynamo. Such occurrences may be averted by a device known as a lightning arrester. Its usual form is that depicted in Fig. 24, which shows an incombustible base upon which are mounted three gun-

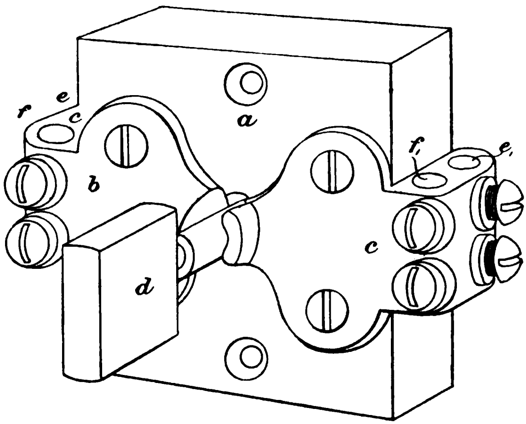


Fig. 23.—Westinghouse Short-circuiting Plug.

metal or copper plates having toothed edges adjacent but not actually touching. Plates *a* and *b* are connected through the fuses and blocks *d* and *e* to the terminals of the dynamo, or preferably to the extremities of the line and return wires of an exposed circuit.

These connections are merely branched or forked off the terminals and end metallically at *a* and *b*. The central plate, *c*, is connected to any metallic body in contact with the earth. Thus aboard an iron vessel

wired on the double plan, it would be connected with the shell of the ship. Ashore it would be connected to a water service or some other good "earth." The tendency of lightning is to readily discharge itself from points and ridges across the shortest gap to earth, and this simple device is merely a means of utilising this fact and to put the exposed wire to earth through a resistance of air sufficient to insure its insulation, but which readily breaks down under a lightning discharge. Still another lightning arrester has been introduced by Thomson and Houston, in which a powerful electro-magnet, with arrangements for magnetically blowing out the electric arc set up by a discharge, is employed.

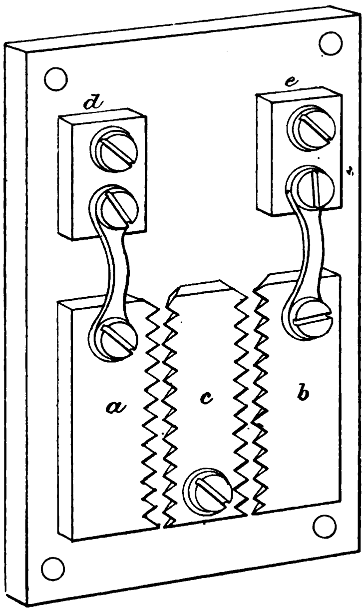


Fig. 24.—Serrated Lightning Arrester.

Indicating Instruments for Marine Work.—It is essential that the smallest installation of the electric light aboard ship be furnished with at least two indicators. These are, a voltmeter, intended to indicate the electro-motive force yielded by the dynamo, and an ampèremeter, to show the number of ampères of current passing into the circuits. Many instruments suitable for use ashore

are furnished with needles or fingers set, compass-like, upon fine points, and require a perfectly level position and must be kept quite still in taking an observation. Others have arrangements, as cores, balanced in wire coils, which must also be kept level and still to insure a reading. All of these, it is needless to say, are unfitted for use aboard a ship. Instruments for use at sea are now a class by themselves. We propose to mention the chief peculiarities of a few of the kinds that have proved efficient in ship-lighting, and as voltage is the first essential condition of lighting we will take the voltmeters first.

Admiralty Type Voltmeter—Cardew's Instrument.—This indicator has in the case of land installations been used chiefly for alternating currents. But it has been employed in the Royal Navy for some years for continuous currents, and also in many of the larger ships of the mercantile marine for the same class of currents. It has the advantage for ship work that it is not disturbed by change of position, and will stand a great deal of rough usage before its accuracy is impaired. It is essentially an accurate instrument, since it has no heating error, nor yet an error arising from self-induction.

Its action depends upon the heating effect of a current passed through a wire. A stretched wire heated by the current expands or becomes longer. If the wire be rigidly held at one end, and at the other be so attached through magnifying gear to a pointer as to move it over a divided scale, it will be obvious that certain readings will correspond with given heating effects upon the wire. The conductor consists of about thirteen feet of platinum silver wire

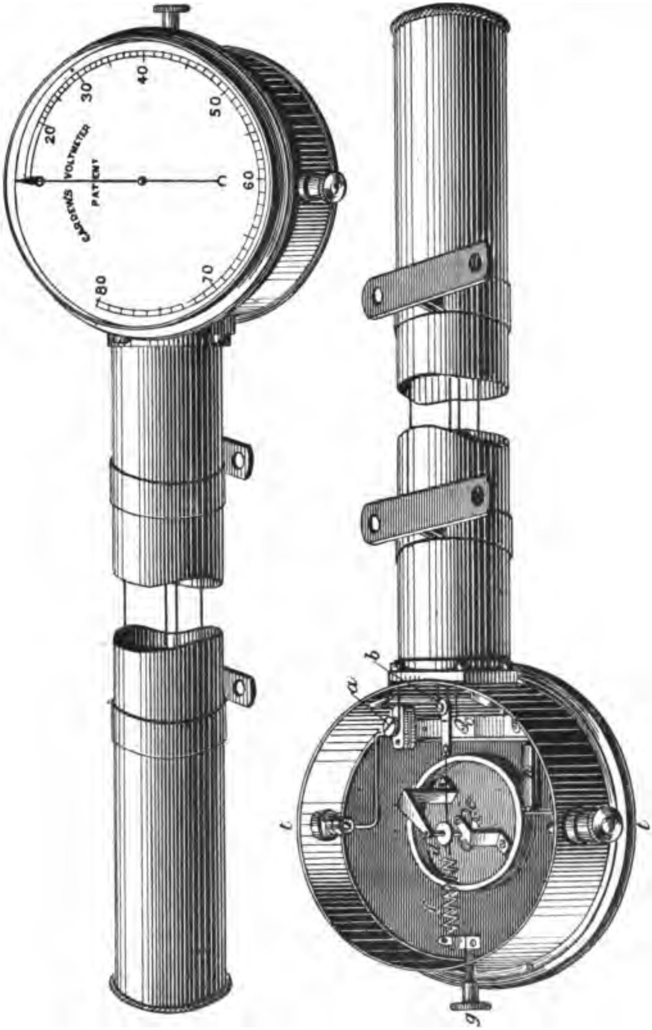


Fig. 25.—Cardew's Voltmeter.

having a diameter of 0·0025 inch. This long wire is disposed of in the instrument as follows :—Referring to Fig. 25, which shows the interior of the voltmeter, the *back* being removed, the platinum silver wire is first attached to a screw marked *a*. From this point it is carried through a long tube (usually three feet in length) to its farther end and there passed over an ivory pulley. The wire is again brought back to the instrument, through the tube, and passes over a second smaller ivory pulley marked *b*. The wire is again carried along within the tube to its farther end and once more passes over an ivory pulley there, and thence back finally to the head of the instrument, when it is rigidly attached to another screw, *c*. The small intermediate pulley, *b*, is attached to a sliding piece, which carries a thin cord which encircles a central pulley marked *d*, and is finally attached to the end of a spiral spring, *f*, which may be adjusted by the external thumb screw, *g*. The pivots of the stem of the small central pulley, *d*, are set delicately in jewelled bearings, the upper of which is set in the cock-piece shown. At the lower end of the arbor ot the pulley there is a toothed wheel, which in turn communicates its motion to the index arbor, *e*. This latter axis is furnished with a hair spring, intended to control the index finger, situated at the other or dial side of the instrument, against back-lash after deflection. Thus when the pulley, *d*, runs through a small angle the pinion arbor, carrying with it the pointer, runs through a large angle, and it is only necessary for the wire to be expanded a very little to deflect the pointer from the zero mark to the full range marked upon the dial.

The current enters the instrument at *t*, and leaves

it at *t'*, through the metallic connections and the safety fuse, *h*, represented. When this instrument is connected to any source of electricity, there is set up a difference of potential between the terminals. This results in a current in the wire, the magnitude of which depends upon the tension in volts and the resistance of the wire. The stretched wire becomes heated and stretches still farther, expanding the spring *g*, and pulling round the small gear wheel *d*. The wire being very thin rapidly acquires its full temperature, corresponding to the particular current passing through it. It is clear that as the spring, *f*, is practically connected to the centre of the length of the wire, it has the pull of both halves of the latter upon it at once, and therefore, although the current heats the whole thirteen feet. of wire, the central point controlling the dial indicator expands and contracts just half as far as it would do were the wire a continuous length of thirteen feet. In other words, it is the expansion of six feet six inches of wire that affects the pointer upon the dial. There are, however, certain advantages in using the fine and long wire instead of a shorter and thicker wire. The chief of these are that the wire rapidly acquires the proper temperature, takes but little current, and it makes the voltmeter dead beat.

The dials furnished with the Cardew voltmeter are usually either of eight or five inches in diameter. The movement of the pointer is thus very large for a small variation in the pressure. Two patterns of the instruments are in use, namely, the rod pattern and the tube pattern. In the tube pattern the tube itself is built up so as to compensate for changes of temperature, and consequent expansion and contraction. In the rod

instrument the working wires are supported by a pair of compensated metal rods, within the tube itself. The rod instrument is largely used at sea, and may be said to be the better of the two for that purpose. The rod instruments may be placed in either a vertical or a horizontal position. The tube pattern must be maintained in a horizontal position. The range of the instrument determines its construction with respect to the gauge of the wire, and the indications upon the dial. A voltmeter ranging between 40 and 150 volts is the most useful instrument for use aboard ship. The instruments may, however, be obtained reading between zero and 50 volts. But it should be pointed out that the Cardew voltmeter is very uncertain in the lower readings, up to about 20 volts. Other instruments than the rod or tube pattern should be used for low readings.

Selection of a Voltmeter.—The rod instrument is accurate over the whole scale when at the temperature of the air, but reads about ½ per cent. too low if left continuously in circuit at a high reading. It is, therefore, well suited for ordinary purposes. With vertical instruments the oscillations of the index limit the accuracy of observation to about ½ a volt over the whole scale.

Oscillation is entirely absent in horizontal instruments, which can, therefore, be read more accurately; but the horizontal position introducing a friction error, the gain in accuracy is very small, so small indeed that in the 150-volt instrument, the advantages are, on the whole, on the side of the vertical pattern. The tube instrument reads accurately under all conditions of working at any ordinary temperatures, being carefully compensated both for expan-

sion and resistance. It was designed, and should be used, as a standard instrument when it is required to measure electro-motive forces of widely different values in rapid succession. This particular pattern is made as a horizontal instrument only, as the extra cost of a tube instrument is not generally warranted unless the oscillations of the needle consequent on the vertical position are eliminated.

Precautions against Fusing the Voltmeter.—The cut-out inserted in each voltmeter made recently will only protect the working wire against fusion in cases where the electro-motive force either rises gradually, or, if applied suddenly, does not exceed, by 100 per cent., the highest reading on the dial. The sudden rush of current consequent on lifting the brushes of the dynamo or in any other way breaking the field-magnet circuit of the machine to which the voltmeter is connected, will probably melt both the fuse and the working wire. A spare fuse is generally issued with each voltmeter, and when it is necessary to rewire the fuses, care must be taken to use the fuse-wire supplied for this purpose. Careless workmen are apt to replace the proper fuse by lead, tin, or even copper wire, and voltmeters are frequently melted by the want of precautions in this respect.

When it is desired to measure pressures over 150 volts a voltmeter in series with one or more resistance tubes must be used, the resistance of each tube being exactly equal to that of the instrument. The voltmeter readings are thus multiplied by two, three, four, &c., according as one, two, or three tubes are in use.

Electro-magnetic Voltmeters.—A considerable number of these have lately been introduced. They are un-

suitable for use at sea unless they possess a spring arrangement in place of the ordinary gravity device for controlling the needle. Paterson & Cooper's instruments for both volt and ampère measurements have been extensively used aboard ship. They consist essentially of a small electro-magnet, taking a very small current through it. Between its poles is arranged the soft-iron electro-magnetic axis of the indicating needle. The latter moves over a dial having a scale of considerable size, so that a fair amount of movement is obtained for each volt put upon the instruments.

Evershed's instruments, depending upon the same controlling principle, are suitable for use at sea when provided with a spring, so as to eliminate the effects of gravity. They are very accurate in their readings. Most of the instruments used in land installations are unsuitable for marine work. The advantages of the electro-magnetic volt and ampèremeters are that they are sufficiently accurate for ordinary purposes, and are not costly.

As permanent magnets are not used in their construction, variations of their strength are avoided. Hence their indications remain the same from year to year. They are not readily affected by currents in neighbouring wirès or magnetism of dynamos. While the Cardew voltmeter is a very long instrument, the electro-magnetic type may be made very small. They are usually placed in a circular case about eight inches in diameter.

Ampèremeters.—Only one or two of the ordinary commercial ampèremeters are available for use at sea. The electro-magnetic type, as manufactured by Paterson & Cooper, have been used with success.

They are almost identical with voltmeters, except in the resistance of the circuit, which is relatively very much smaller.

Sir William Thomson's Marine Voltmeter.—This is a very compact and portable form of voltmeter. It consists essentially of a stretched length of platinoid wire, which carries a small oblate of soft iron situated in the centre of a solinoid of fine copper wire. Attached to the iron oblate is a pointer, moving over a graduated scale. The scale is subdivided into fractions of volts. In order to vary the value of the divisions upon the scale a set of resistances is used with the instrument. The principle of its action is that the iron oblate tends to rotate its equatorial plane parallel to the lines of force in a uniform magnetic field. The pointer is so attached to the oblate that when it indicates zero the equatorial plane of the oblate is inclined 45° to the lines of force set up by the current in the solinoid. Owing to the fact that such solinoids are subject to inductive effects from without, due to currents in neighbouring conductors, this part of the instrument is enveloped in a thick tube of soft iron. This is cut away at the portion where the pointer passes to the exterior scale. The means of adjusting the instrument are affixed to the case. The resistance of the solinoid is 1,000 ohms when intended for work on 100 volt circuits.

Voltmeters for marine work may be broadly divided into two classes: first, instruments depending upon the heating property of the current; secondly, instruments depending upon electro-magnetic attraction or repulsion, or both together. The first class embraces all the stretched wire voltmeters, of which Cardew's is the best known for marine work. The second class is

a numerous one, and embraces the Crompton and Crabbe instruments, Paterson & Cooper's, Evershed's, and several others. Many of these are available for ship's use by being made independent of the action of gravity. This latter is an essential condition in a marine volt or ampèremeter. There is still another condition: instruments for ship's use are generally subjected to a good deal of heat, and should not therefore be constructed of materials, such as ebonite or wood, subject to deterioration by heat.

Distributing Circuits Aboard Ship.

There are two distinct methods of wiring a ship for the electric light. These are, the *double-wire system* and the *single-wire system*. Each method has its advocates.

The principle of the double wiring is that of all ordinary electric light circuit work ashore, namely, the running of two wires parallel to each other, and connecting the lamps across them, as it has been aptly termed similar to the "rounds of a ladder." In practice the wires do not generally run in pairs. The return may be made by a general wire, serving for several circuits. But the essential condition is that both the leading wire, or that conveying the current, and the return wire, or that bringing back the current, shall both be *insulated*.

It is understood that the "leads" and "returns" are not only insulated from each other, but from every other wire, and from the *earth*. The circuit is a completely isolated metallic circuit as far as the wires extend. This, in a word, is the double-wire system. It is essential in the case of all house wiring, although

the insulation of the return wire is sometimes dispensed with, for the sake of cheapness.

The Principle of Single Wiring.—If we suppose the case of a house made entirely of iron it will be seen that the temptation to dispense with a return wire, and to make the current flow back to the dynamo through the iron of the house, is very great. The more so as it is a fact that this can not only be done, but that the arrangement performs very well. The leading wire is in this case insulated as usual, and the iron of the building is regarded as the return wire. There is thus the great convenience of a return being available at every part of the building, without the trouble of bringing it there. In addition, no small part of the inducement to dispense with the return wire is due to the decreased expenditure for the wiring, which not only costs but one-half for copper, but very much less for labour.

These are a few of the arguments from the contractor's point of view, but the electrician has his arguments in favour of single-wiring also. He considers that whereas with the twin-wire system he has two wires to look after, and to preserve the insulation of, with the single wire system this responsibility appears reduced to one half. There is only one wire to preserve in an insulated condition. All these arguments in favour of single wiring have a very specious appearance. But there is another side to the question.

Arguments for and against Single Wiring.—The method of running lamps from a single wire has its opponents. They bring forward forcible reasons tending to show that single wiring is inferior to and less safe than double wiring. The mere prejudice of individuals against the idea of "earthing" the whole

of the return must be abandoned in a controversy of this kind. It resolves itself into a matter of practical efficiency. The case stands thus: the ship is a complete shell of iron or steel; the shell is crossed and fitted up in a complex manner with divisions called bulkheads and other divisions that are not bulkheads; with railings, steam-pipes and water-pipes. The whole forms an immense metallic structure with many and complex ramifications. It may be regarded as an entirely metallic building, in which even the beams, floors and stairways are of iron. The half of this mass of metal is immersed in water. Therefore the whole of it is in intimate connection with the *earth*. Hence, again, it forms what a telegraphist would term a great *earth-plate*, or simply an "earth." If the double wiring employed in a dry house of brick, plaster, and wood ashore be employed in fitting up such a structure as an iron ship, we are likely to have complaints of failure of the light. The reason is not far to seek. The insulation that would suffice in the house is insufficient in the case of the ship. In the supposed house the brick, plaster, and wood are practically insulators in themselves. If a wire be run naked across a dry floor, or even along dry plaster, it may perform its part as an electric light lead fairly well. If the wire be lightly insulated and run in wood casings it is not likely to give any subsequent trouble. In a word, *earth* contact is not at hand, and a second wire to serve as a return is a necessity. There is little tendency to leakage of current from the leading wire to the return wire; leakage could only occur by the help of an accidental cross between the lead and the return, or by the presence of some conductor, as water.

In a ship, on the other hand, *earth is everywhere*. There is the risk of earthing the current during the course of every yard of wire. If we suppose the leading wires and returns simply cleated to the iron of the ship it is not difficult to suppose that leakage is liable to occur across the metallic space between the two, even when the ordinary insulating covering of the wire is intact. *Insulated wire* is a misnomer. It is not strictly insulated. The covering is easily broken through by a sufficient pressure. This is easily tested. If a coil of wire be immersed in water, and a test be taken, it will be found that its insulating *resistance* is so many ohms: that it is by no means infinite: that it is simply not insulated. But there is an enormous difference between a naked and a thinly-insulated wire. A mere coating of tar or varnish will suffice to exhibit an insulation resistance of many thousand ohms. Hence, we may continue to term wire covered with vulcanized indiarubber insulated, because leakage from such a conductor, when the pressure at the dynamo does not exceed 150 volts, is very small indeed. Still we are confronted with the fact that the wire must be run in the ship close to a great adjacent "earth." There is, therefore, a greater tendency to leakage than in a house. In other words the insulation resistance is less. If, however, we employ wire so thoroughly insulated as to be capable of showing a very high insulation resistance, and run that class of wire through the ship, in the double plan, we may consider that what we have to look for in the way of faults are leakages from one wire to the other. The insulation resistance, it is calculated, is required to be so many thousands of ohms to render the insulation

safe under pressure of a 100 volts. It must not be overlooked that this insulation resistance is that due to *twice* the covering upon one of the wires, because a leak must cross from one wire to the other through *both* coatings.

Insulation halved by Single Wiring.—It is now clear that if we decide that the insulation must show a resistance of so much for the double plan, the wiring of the vessel upon the single plan exactly halves that resistance. It has been well said by opponents of single wiring that it is equivalent to halving the insulation. On the single-wire plan every part of the ship is the return wire. We have only the insulation of one wire between us and the return. Hence it will be plain that *single wiring demands nearly double insulation.* This, indeed, is its chief drawback, and it has many advantages to offer against this disadvantage. It is true that if, on the double plan, water were to find its way to the return wire it would not effect a leakage of current unless a similar dampness extended to the leading wire also, and, therefore great faults of insulation, with regard to earth, might not materially affect the working on the double-wire plan.

Liability to Leakages from Single Wiring.—If on the other hand the wiring be on the single plan the risk of leakage is greatly increased, even if we furnish it with double the insulation usually applied to double wiring. When there is a ship return, it is clear that a leak from the lead to the iron of the vessel may occur by the mere chance of water finding its way through the insulating material at any point. There is, in fact, a closely adjacent earth during the whole course of the leading wire. This fact demands that

good work shall be put into the wiring at the outset, and that a close watch be kept upon the insulation resistance thereafter.

Plan of the Lighting Arrangements.—When a ship is to be lighted, the first matter to be settled is the number of lights required. The candle-power of the lamps comes next in importance. Then the number of separate circuits to be run, and finally the kind of wiring to be employed, whether single or double.

Number of Lights required.—Lighting aboard a ship is so difficult, owing to the confined space and the obstructions to the diffusion of the light, that a larger number of lights is called for than would be necessary in the case of a house. Taking the *saloons* first, the lighting is preferably done from above in those when there is sufficient height of roof. In the case of some of the largest Atlantic liners the saloons are domed, and the lighting is chiefly effected from the dome, and aided by side lights placed near the roof. Domed saloons are, however, the exception, and the lamps have generally to be placed close to the ceiling. They must be disposed so as to be as much as possible out of the way. Owing to the limited height of saloon roofs, the lamps are liable to damage, and they are preferably distributed on the line of such fixtures as saloon tables, and close to the sides, over the couches generally occupying that position.

In order that they may be available for reading purposes they should be kept as close as possible over the back of the couches. At the least a lamp will be required to every space ten feet square. Sixteen-candle power lamps are generally used for saloon and *cabin*, *library*, *smoke-rooms*, and so on, occupied by passengers. It is convenient to class all of these "public" apartments as

one, and to arrange for the lighting of them by means of one, two, or more exclusive circuits.

Next in importance come *state-rooms* and *berths*. These are comparatively easy to light. As a rule one lamp of 16-candle power will suffice for each. It is usually attached to a bracket affixed to the wall near the roof. These may be said to embrace all of the "public" lighting excepting the *steerage*, which is generally of much importance in large vessels proceeding west. The steerage lights are usually run upon a circuit by themselves. The only difference between the lighting of this part and that of the saloons lies in the possible provision of fewer lights, and those of smaller candle-power, with the extra precaution that lamps are placed as much as possible in inaccessible positions and protected by strong guards.

The *pantry*, *galley*, *bar*, *passage*, lavatory lights, and those in the officers', servants', and men's quarters, are conveniently run off a circuit to themselves. The *navigating lights*, as *head light*, *side lights* and *compass lamps*, should be upon a distinct circuit. *Engine-room*, *stoke-hole*, *tunnel*, and *store-room*, including *bulkhead lights* below water line, should be put upon one or more circuits entirely separate from other lights. In the case of a war-ship the lights that are used in unprotected positions should be quite separate from those illuminating the vital parts of the ship, such as the engine-rooms, stoke-hole, magazines and stores. The reason for this will be more apparent when we consider that if the mains feeding the protected (armoured) parts of the vessel send out branches into unprotected positions, a shot might, by damaging the latter, establish such a short-circuit in them as to cause the main fuses to melt, and put the more vital parts of the ship

in darkness. In the case of war-ships also, the navigating lights, those for the binnacle, for the signalling platform and the flash or search-light, should be fed by a separate circuit carried as far as possible under the protection of the armour, so as to reduce the risk of extinction in the event of the bursting of shells or the impact of shot.

Canal lights, which are generally used betwen *Suez and Port Said*, and also for *river* and *fjord navigation*, are generally arc lamps slung over the bow. They should have a circuit of their own.

Fore and aft Division.—The engine and dynamo-rooms of large vessels generally occupy a central position lengthwise of the ship. This affords a convenient means of setting out the circuits into three chief divisions into *Fore accommodation and stores*, *after accommodation and stores*, and *central circuit*, embracing the engineering departments.

It will be readily understood that it is impracticable to furnish the reader with particular information relating to the distribution of the lighting, owing to the fact that every ship is in some respects different from any other. We can only go upon general lines, and indicate broadly the practice of lighting as it applies to vessels in general. In our brief glance at the division of the lighting we have supposed that the ship is a large one, carrying passengers, because that type affords also an example of the kind of arrangements suitable on a diminished scale upon smaller vessels and those exclusively engaged in cargo work. The constructive details are, however, a matter affecting the circuit work, and so are the practical requirements of the lighting. It should not only be clear where there are watertight bulkheads, but when and how

these may be safely pierced for the conveyance of mains. Information should be available as to the various classes of lights that are usually switched off together and those that are always burning, so that main switches may be placed where they will prove useful. For example, it would be inconvenient to put a line of berths upon the circuit lighting a saloon, because that circuit will generally be switched off entirely about 11 P.M. and the room lights may be required at any time in the night. Again, store-rooms, refrigerator compartments, and such places under the water line, only entered once or twice in the day, should not be grouped upon a circuit which is "off" during the hours of daylight.

Section lighting is necessary because it reduces the number of lamp switches and cut-outs, so that such places as saloons and steerage should be controlled generally by a single switch, which may be used to turn on all of the lights at once. It is quite impracticable in such cases to furnish each lamp with a switch of its own. Hence, these larger sections must have their independent circuits, and no lights that are likely to be wanted when they are "off" must be placed upon their wires.

These considerations will serve to indicate the chiet points in the arrangement demanding thought before laying out the plan of the wiring, and it is worth while to point out that the consideration of mere convenience in getting the lighting done should be put aside, and the fact that the convenience of the arrangements when completed, during after years, should be the first thought. This is especially true of the way circuits are laid out. Mere convenience of getting the wires run is often the first consideration, whereas it

should be the last. It is far more important to endeavour to foresee the future of the installation, when the woodwork will possibly be soaked with water, or blistered with heat, or other changes, due to the working of the ship, occur.

The convenience to the attendant, in obtaining access to joints, cut-outs, and the general run of the mains and branches, should be a first consideration. For example, it would be very undesirable to place the main fuse governing the saloon lights within the refrigerator or store-rooms, which are usually kept locked except at stated times. Or to place the controlling devices of the circuit of one watertight compartment within another, which may possibly become flooded, and so cut off the light from both.

Accumulators in Reserve on the Circuits.—To a certain extent the employment of a storage battery may be said to affect the circuits. Accumulators are generally kept in the circuit as a regulator even while the engine is running. They are admirably adapted for this purpose when the dynamo is run off the main engine. But their regulating assistance is not to be despised when the dynamo is moved by an independent engine. Information concerning the handling of accumulators will be found in Chapter IX. Generally speaking, they may be regarded as a second source of electricity, simply auxiliary to the dynamo, and circuit arrangements that will suit the dynamo will also meet the requirements of the accumulators, if we except the necessary connections and switch for cutting the battery, or parts of it, into and out of the circuit.

Reserve Dynamos and Duplex Circuits.—In the early days of electric lighting it was no uncommon matter to

see twin sets of both dynamos and circuits extending to every important part of the ship. The experience gained in a great deal of ship-lighting during the past ten years, shows conclusively that, however desirable it may be to provide a reserve dynamo, such precaution in respect of the circuits is quite superfluous. To instal twin circuits implies a tacit want of confidence in both. It means that the future of the circuits cannot be so far foreseen as to enable the wireman to anticipate the points of possible failure. At the present time, circuits need not be duplicated except perhaps in the case of a war-ship, part of which may at any time when in action be blown away, carrying the wires with it. Even in battle-ships such contingencies are foreseen and as far as possible provided for.

In respect to the question of reserve dynamo, year by year these machines are becoming more and more perfect. The points and chances of breakdown are becoming so well known that they can generally be provided against. It is not too much to say that duplication of even dynamos is practically a thing of the past. In the largest and most luxuriously-furnished liners sailing from Liverpool, London, and Havre, partial and not complete duplication of the dynamos is the rule. As an instance, the White Star ship *Majestic* is fitted with 1,200 incandescent lamps, the ship carries four dynamos, each capable of maintaining, easily, 400 lamps.

There is thus always a reserve dynamo out of the four standing idle. This proportion of reserve power is found to be amply sufficient. It allows of any machine which may be running hot, being switched off for a time; the reserve one being switched into its

place. Similar arrangements prevail aboard other important vessels. The conclusion we arrive at is, simply, that *a good dynamo and circuits need no reserve.* They should be capable of working for weeks at a stretch without overheating.

Quite another thing is a little reserve power in the dynamo itself. Thus a vessel burning 400 lights would be well furnished with a dynamo capable of giving at full load an output sufficient for 500 lights. Thus the machine is always run at less than full load, and is more likely to withstand long runs and to keep cool generally. We should thus, generally speaking, be disposed to recommend the carrying of but one dynamo, in the case of small vessels. The machine should be of the compound-wound type if accumulators are not carried, and of the shunt-wound type if electric storage is resorted to. The dynamo should be of ample capacity. A machine working generally up to ninety per cent. of its full load would appear to be the smallest that it would be advisable to adopt. In the case of large ships it is doubtful if the present arrangements are likely to be much improved. Each dynamo, compound wound, is independent of the others, and is moved by a separate engine. These questions are discussed more fully in Chapter III.

Cut-outs or Fuses at the Base of Branches.—We have already spoken of cut-outs at the beginning of the main wires themselves. Fuses at the beginning of the branches where they leave the main are equally necessary. There is only this difference between them and those used at the switch-board: they are necessarily of smaller sectional area, so as to melt at any addition to the full current the branch is estimated

to carry safely, and they must be fixed in *water-tight cases.* Cast-iron boxes, packed so as to be water-tight, are now manufactured for this purpose.

Data relating to Cables and Wires for Mains and Branches.—The small table given on page 151 contains a good deal of useful information. It is all based upon the assumption that a current amounting to 1,000 ampères can be carried by a conductor having a sectional area of one square inch with perfect safety. This implies that such a current would not sensibly warm such a conductor so as to endanger its insulation. But although this limit was first suggested by Sir William Thomson, as a precaution against the risks of fire, it is very frequently exceeded in practical work, especially in branch wires. The Board of Trade rule suggests a current as high as 2,000 ampères per square inch, as an extreme limit, and although wiremen seldom attempt to reach so high a figure, even this limit may be said to be safe if the wires are well protected by fuses. Generally speaking, however, it is well to work to the lower limit, because it possesses the merit of allowing a good margin of safety. Cols. 3 to 6 give the approximate number of lamps usually run upon the branch wires below; the lamps being specified as taking so many watts altogether. It would be better to work to a rule giving the watts per candle, were it not that the consequent calculations would provide a less ready means of estimating for wires by ordinary workmen. Col. No. 7 gives the size of tin wire that should be used for fuses upon the opposite wires. But the position of a wire fuse affects its breaking limit so greatly that the figures can only be taken as approximate.

Handy Table for Incandescent Wiremen.

At 1000 *Ampères per sq. in.* 2·55 *Volts are lost for every* 100 *yds. of flow and return.*

Size Standard Wire Gauge.	Current at 1000 Ampères per. sq. in.	No. of 110 Volt, 64 Watt Lamps.	No. of 100 Volt, 64 Watt Lamps.	No. of 60 Volt, 60 Watt Lamps.	No. of 45 Volt, 60 Watt I amps.	Tin Fuse Wire. B.W.G.	Approximatefusing current Ampères.
Col. 1	2	3	4	5	6	7	8
18	1·8	3	3	2	1	30	3
16	3·2	5	5	3	2	24	5
14	5·0	9	8	5	4	22	7·5
7/20	7·2	12	11	7	6	20	10
12	8·5	15	13	8	7	18	15
7/18	12·8	22	20	13	10	17	20
7/17	17·4	30	27	17	14	16	25
7/16	22·9	39	36	23	18	14	40
7/15	28·9	50	45	29	23	13	45
7/14	35·6	61	57	36	28	2-14	80
19/16	62·4	107	98	62	50	2-13	90
19/15	78·9	137	123	79	63	3-14	120
19/14	97·3	167	152	97	78	4-14	160

The following table is much more comprehensive. The sectional area of each size being given enables the wireman to work to any limit of current and conductor. Cols. 12 and 13 will be found useful as giving the resistance (approximate) in ohms of the usual wires. The number of lamps given opposite to each wire must also vary according to circumstances.

TABLE OF ELECTRIC WIRES AND DATA RELATING THERETO FOR THE USE OF INCANDESCENT WIREMEN.

From the Author's "Electric Light Fitting."

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
Standard Wire Gauge.	Number of Wires (if stranded)	Diameter				Equivalent to Solid Wires.				Length and Weight	Weight and Resistance.		Safe Working Current on the Basis of 1000 Ampères per sq. inch.	Approximate number of Lamps usually run off the wires.	
		of each Single Wire.		of the Strand.		Diameter.		Sectional Area.							
		inch.	m/m.	inch.	m/m.	inch.	m/m.	sq. in.	m/m.	Pounds per 1000 ft.	Ohms per 1000 ft.	Ohms per lb.	Ampères.	45 to 60 volt lamps.	90 to 110 volt lamps
22	1	·028	·711	—	—	·028	·711	·0006	0·397	2·37	13·167	5·54848		—	1
21	1	·032	·813	—	—	·032	·813	·0008	0·518	3·10	10·081	3·25229	0·8 to 1·0	1	1
20	1	·036	·914	—	—	·036	·914	·0010	0·656	3·71	8·427	2·27254	1·0 „ 1·5	1	2 to 3
19	1	·040	1·02	—	—	·040	1.02	·0012	0·810	5·34	5·852	1·09596	1·5 „ 2·0	2	3 „ 4
18	1	·056	1·22	—	—	·048	1·22	·0018	1·167	7·27	4.299	·59157	2·0 „ 2·5	2 to 3	4 „ 5
17	1	·064	1.42	—	—	·056	1·42	·0024	1·588	10·17	3·069	·30135	2·5 „ 3·0	3	5 „ 6
16	1	·072	1·62	—	—	·064	1·62	·0032	2·075	12·79	2·443	·19104	3·0 „ 3·5	3 to 4	6 „ 7
15	1	·080	1·83	—	—	·072	1·83	·0040	2·626	15·69	1·991	·12699	4·0 „ 4·5	4	7 „ 8
14	1	·092	2.03	—	—	·080	2·03	·0050	3·242	20·85	1·498	·07186	5·0 „ 5·5	5 to 6	8 „ 9
13	1	·104	2·34	—	—	·092	2·34	·0066	4·287	27·32	1·144	·04187	6·0 „ 7·0	6 „ 7	10 „ 12
12	1	·116	2·64	—	—	·104	2·64	·0085	5·480	35·96	·869	·03416	8·0 „ 9·0	7 „ 8	14 „ 16
11	1	·128	2·94	—	—	·116	2·94	·0105	6·774	43·59	·717	·01645	10·0 „ 11·5	9 „ 10	16 „ 18
10	1	·144	3·25	—	—	·128	3·25	·0128	8·302	54·35	·575	·01058	12·0 „ 13·5	10 „ 11	18 „ 20
9	1	·160	3·65	—	—	·144	3·65	·0162	10·50	66·30	·471	·00711	15·0 „ 17·5	12 „ 14	24 „ 28
8	1	·020	4·06	—	—	·160	4·06	·0201	12·97	82·41	·379	·00460	20·0 „ 22·5	16 „ 20	35 „ 38
25	3	·024	508	·042	1·07	·034	·863	·0009	0·585	—	—	—	—	—	—
23	3	·028	·609	·051	1·29	·042	1·006	·0014	0·893	—	—	—	—	—	—
22	3	·020	·711	·059	1·50	·049	1·24	·0019	1·216	—	—	—	—	—	—
25	7	·020	·508	·060	1·54	·053	1·35	·0022	1·423	—	—	—	—	—	—
23	7	·024	·609	·072	1·83	·064	1·62	·0032	2·075	—	—	—	—	—	—
22	7	·028	·711	·084	2·13	·075	1·90	·0044	2·849	—	—	—	—	—	—

Iusulated Wires.—All copper wires are supposed to be of the highest conductivity, which generally implies any figure between 90 and 100 per cent. They are usually tin-coated to prevent action upon the rubber coating. They are then served with a coating of pure rubber. The thickness of this upon single wires is seldom less than the diameter of the wire itself. As a mechanical protection there is placed above the rubber a coating of tape, having a thickness equal to half the diameter of the wire. The whole is then vulcanized together. It is generally still further served with coatings of insulating and stiffening varnish or "compounds."

The above is ordinary insulated wire for electric light work. There are usually at least two grades of insulation above that specified. The first consists of an increased mechanical protection, in the form of a braiding of cotton above the ordinary tape. This is finally varnished waterproof. The second consists of a still better or thicker coating of rubber upon the naked wire, the coatings of tape, braid, and varnish being the same as before. The insulation resistance, which in the cheaper variety only amounts to 300 megohms, rises to as high as 750 megohms in the better class.

Stranded Wires, Cables.—Wires thicker than No. 12 of the standard wire gauge are very stiff to handle. They are too stiff, when insulated with hard rubber, to bend freely around corners. Hence it has become the practice to limit the single wires to the sizes between No. 18 up to No. 12 or 14. It is found more convenient to strand several smaller wires together in place of a large single wire. The strand is more flexible than the latter. Hence the practice of following up No. 12 or

14 not with a No. 10 wire, but with a small cable formed by twisting seven No. 20 wires together, and to follow that by a cable having seven No. 18 wires stranded, and so. The insulation of these cables is the same as that of single wires, but thicker in proportion. It is convenient to term the single conductors wires and the stranded conductors *cables*. The larger cables, such as 19/16 wires stranded, are generally used for *mains*; the smaller stranded wires, as 7/18 wires stranded, as *sub-mains*; and the single wires down to as fine as No. 20 as *branches*.

Twin Wires.—*Wandering leads*, or wires attached to a wall or roof connection, and attached to a portable lamp, consist of two very flexible thin cables separately insulated, but braided together, so as to form mechanically a single conductor. They are generally formed of the following wires:—7/32, 11/32, 19/32, 30/32, 53/30, and some to convey current sufficient for one or two lamps.

TIN-ALLOY WIRE USED FOR FUSIBLE CUT-OUTS.

Size S.W.G.	Fusing Current Ampères.	Size S.W.G.	Fusing Current Ampères.
14	30	26	3
15	25	28	2·25
16	22	30	1·75
18	14	32	1·47
20	9	34	1·0
22	6	36	0·6
24	4	—	—

These wires are usually made from tin alloyed with a large proportion (sometimes an equal proportion) of bismuth to give them greater resiliency.

Fusible slips, used in small cut-outs, are generally made from an alloy of Arcet's metal nine parts and mercury one part. They fuse at about 50° centigrade. Still stiffer fuses are made, which fuse under the heat of boiling water, from tin 3, lead 5, bismuth 7. A still less fusible wire, going at about 285°Fahr., consists of equal parts of bismuth and tin. Fuse strips and wires made according to any standard system are generally stamped with the maximum current they will carry without melting. It was at one time a general practice to work fuses with the number of lamps they would be reckoned to supply, but this was extremely misleading. No two lamps take the same current save by the merest chance, and "lamp" might mean anything from an 8-candle lamp to one of 32 candles.

Leads for Cargo Lanterns.—The smallest conductor usually employed for cargo lamps is generally a pair of flexible cables composed of ten No. 40 wires. This would carry current for one or two lamps only. The next is 130/40 wires, then 7/20, 19/22, 19/20.

Fusing Points of Branch Wires.—Careless or ignorant workmen have been known, when a fuse has melted, to put in its place a copper wire. The temptation to do this is sufficiently great, but it can form no excuse for endangering property by the risk of fire. In some cases it is true that upon an emergency, when a fuse wire is not at hand, and the circuit must be fed at all hazards, a copper connection may have to be thrown across a fuse, but it should be removed at the first available opportunity. If any such emergency should arise it may be well to state that the piece of wire selected for the purpose must be *very much* thinner than the branch to be fed. Copper wire makes a bad fuse, its melting point is too high, and it does not readily

break the circuit, when it happens to be supported, even after that limit has been exceeded. The following are the fusing currents of the common wires:—

S.W.G.	Copper Wire Fuses at, Ampères.	Corresponding Currents for Tin-head Alloy, Ampères.
14	231·8	29·82
16	165·8	21·34
18	107·7	13·86
20	69·97	9·002
22	48·00	6·175
24	33·43	4·300
26	24·74	3·183
28	18·44	2·373
30	14·15	1·820
32	11·50	1·479

Reputed and actual Gauges of Wires.—The reputed gauge is not always the actual gauge of a wire. It is convenient to carry a standard wire gauge and to test every wire. Errors in this particular may lead to very serious faults in the wiring. The ordinary gap gauges made from steel plate may be obtained of sufficient accuracy. Mr. Trotter's slide gauge is, however, much more useful. It is provided with four scales. It readily gives, by means of a vernier, the number of the wire, its size or diameter in inch parts and in millimètres. It also gives its sectional area, which determines its current-carrying capacity.

Enumeration of Wires in Cables.—It is frequently a tedious process to count the number of wires in a stranded cable. Persons used to the different sizes can generally tell at a glance how many wires, and of what sizes, a given cable consists. This faculty is easily acquired by bearing in mind that in a cable of seven wires, one is central, with six others around

it. In a 14-wire cable the centre consists of four wires. A 19 cable looks like a 7 strand, having a central wire, with an additional circle of wires exteriorly.

It is a growing practice to diminish the sizes of the wires cables are made up of, and to put an additional number of them into their composition. This results in greater flexibility, but it demands greater care in jointing and connecting.

Lead-armoured Wires and Cables.—In addition to the insulating covering already specified wires and cables are sometimes enclosed in a closely embracing tube of lead. This kind of mechanical protection may also be regarded as an addition to the insulation, inasmuch as it prevents water from access to the core of copper. The lead-armoured cables are intended chiefly for underground work or for running in water, but they are used largely for ship wiring, to which purpose they are specially suitable under certain conditions. It is plain that if a cable and its connections can be completely encased in lead, all trouble from damp, &c., must be at an end. But there are two difficulties in the way of the general adoption of lead-covered cables. These appear to be the obvious difficulty of making good the joints between the lead covering of the mains and their branches; and the electrical difficulty of insuring that there shall be no contact between any part of the case of any cable and the exterior lead sheath. It is plain, with reference to the latter, that any contact of this nature *puts the whole of the core to earth.* There is, in short, a *very near* earth, ever liable to be connected to the core. It may be that the insulation breaks down, and the fancied protection becomes a source of the greatest annoyance.

Notwithstanding these drawbacks, the lead-covered cable and wire also are well-adapted for ship wiring on the *single-wire plan*. In order that the system may work at its best *the return should not be completed through the lead sheath*. The latter should be regarded and treated as so much insulation. It should not come into contact with the metal of the ship at any part. The sheath thus becomes a completely isolated, if not insulated, tube of metal. If contact be accidentally made between it and the core of the leading cable, that contact will not cause any short-circuit nor loss of power. There will be no risk of making a circuit through the sheath. The advantages of the lead covering used in this way are, first, that cables and branches can be run in mere wood cases. No insulating precautions need be taken, save separation by wood from metal work. If water should get to the sheath it cannot penetrate it. The core and insulation are kept in a perfectly dry state, the lead sheath is therefore proof against damp. Secondly, cables so protected are less liable to damage mechanically, and the wires need not be run in such inaccessible places. And thirdly, if it be desired to risk making the sheath part of the *return*, all wood casings may be dispensed with, and mains may be cleated down to metal work direct—this is in fact frequently done, with perfect success.

Jointing Materials.—It is essential, before undertaking the running of circuits, to possess a knowledge of the materials and processes used in making the connection between mains, and between those and branches. The most useful materials for ship electric jointing, are as follows :—

Pure India-rubber tape in two widths, ¼ in. and ¾ in.
Prepared black tape, proofed on one side. Ditto proofed both sides.
India-rubber solution.
Compound India-rubber sheet for vulcanized joints.
Vulcanizing composition.
Chatterton's compound.
Strong (thick) shellac varnish.
Spirit lamp cotton.
Wood naphtha.
Felt tape.
Ozokerite tape.
India-rubber coated tape.
Copper binding wires, sizes Nos. 30, 28, 26, 24.
Tinman's solder.
Resin.
Baker's soldering fluid, or solution of zinc chloride.
Emery cloth, Nos. FF and F.
Portable soldering furnace.
Spirit jointing lamp.
Small bench vice; hand-vice.
Soldering bolt-copper.
Tinned wire, fine, for jointing.
Three pairs pliers—front cutting, side cutting, round nose.
Insulation knife, scissors.
Flat file, smooth cut.
Brace and bits, saws, chisels, gimlets, hammers, screwdrivers.
Shifting spanner, drill-brace, breast-type, to drill up to ¼ in., set of twist-drills.
Ratchet-brace and drills for piercing bulkheads.

Most of these wireman's tools should be kept in a suitable tool-chest, and a chest of pine 25 × 15 × 12 in., with loose tray, will be found a useful size. Information as to processes of jointing is given further on.

Plan of the Mains and Branches.

Perhaps the most instructive way to introduce this subject is to give a table of the actual electrical requirements aboard a large passenger vessel. The table contains six circuits appertaining only to the *Port* side of the ship.

Wiring and Circuits of the R.M.S. "Majestic." Port Side only.

Circuit No. 1, Engine room, port.	No. of Lamps.	Circuit No. 2, Main Deck, aft.	No. of Lamps.	Circuit No. 3, Lower Deck.	No. of Lamps.	Circuit No. 4, Main Deck, for.	No. of Lamps.	Circuit No. 5, Main Deck.	No. of Lamps.	Circuit No. 6.	No. of Lamps.
Tunnel	8	Starboard half of 1st class smoke room.	21	Pantry, galley, butcher and baker	40	Port half of main saloon.	27	Main deck alley ways ...	10	Daylight saloon	4
Refrigerator room ...	3	Starboard half of 2nd class saloon	7	Glory hole ...	9	1st class state rooms forward, port ...	28	Mid deck bar...	16	Surgeon and purser	6
Bottom platform ...	20	2nd class state rooms	39	Steerage, aft...	10	1st class w. c.	2	Port hole 1st class smoke room	18	Upper deck baths	6
Mid platform	22	1st class state rooms, bath, w. c., &c. ...	26	Firemen's rooms	19	Skylight over library ...	16	Ash lift hold ...	2	Engineers' bath and pantry	4
Top platform	5	Starboard steaming light (side light)	2	1st class state rooms fwd., port and starboard	23	Main deck steerage, forward	10	Firemen's lavatory ...	2	Emigrants' lavatory	3
Sockets for portable lamps...	3	1st binnacle (compass lamp)	1	Starboard 1st class baths, passage, and w. c.'s	9	Steerage stairs	1	Engineers' rooms	19	Mid deck 1st class forward state rooms	15
Skylight lamps, three of these 50 c. p. ...	9			Steerage for married couples ...	22	Lower deck steerage, for.	13	Emigrants' entrance and bath aft ...	2	Passage, fwd. aft. saloon main deck	31
Engineers' stores ...	3							Cargo lantern	10	Firemen's stairway	2
Stoke-hole, gauge-glass lights	14							Stewards' entrance, aft ...	1	Barber's shop, and passage	5
Sockets for portable lamps, con. boxes ...	7									Lavatory aft. engine room.	4
Fan recess lights ...	8									Midships state rooms ...	15
Stoke-hole tunnel ...	2									Passages aft. engine room	13
Sockets for portable lamps over boilers .	12									Lower deck passages ...	20
Firemen's stairway ...	2									Boot room	2
Sockets for portables in refrigerator room	2									Bunker lights	24
										Baggage and specie	3
										Refrigerator...	11
										Refrigerator sockets for port lamps...	4
										Main stairway	2
										Electro-motor in barber's shop	5
										Chief steward's room... ...	2
										Steward's stairway	2
										Refrigerator coil chambers	4
										Upper fans, aft.	2
Total on No. 1 Circuit	120	Total on No. 2 Circuit	96	Total on No. 3 Circuit ...	132	Total on No. 4 Circuit ...	97	Total on No. 5 Circuit ...	80	Total on No. 6 Circuit	187

Separation of the Electrical Supply.—In the fore-

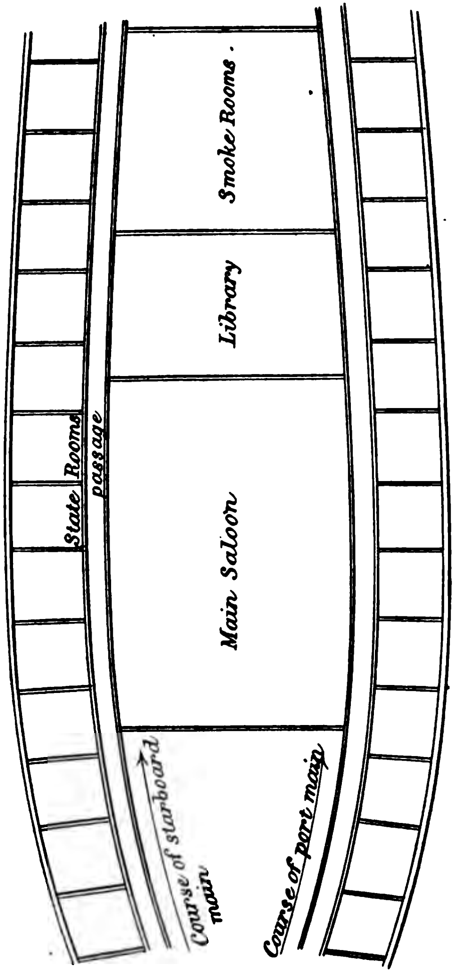


Fig. 26.—Plan of Upper Deck showing accommodation to be lighted.

going enumeration it will be clear that a system of

separating the supply of current into two equal halves has been to a great extent carried throughout the whole scheme. What is meant by separation or independent supply is this:—In the ship in question there exists a longitudinal bulkhead running through the engineering department. The propelling power of the vessel consists of two independent sets of triple-expansion engines, each working its own stern propeller. Hence, the engine-power is divided into two equal parts. If, by an accident, one part or half became disabled, or that section of the ship filled with water, the other half would still be able to maintain a fair headway upon the vessel. Thus starboard is quite independent of port. In the same way the four dynamos are placed, two upon each side of the bulkhead. Starboard dynamo-power is thus independent of port dynamo-power, and a complete breakdown of one set would not disturb the other. Again, starboard electric lamps are distinct from port lamps. These *two sets* of lamps are ingeniously brought into every department of importance. The aim of this arrangement is that, while the saloons are lighted, half by starboard dynamos and half by port dynamos, the breakdown of either set of dynamos would only extinguish *half* the lights in these departments, thus leaving a fair amount of light.

Fig. 26 represents an imaginary area to be lighted upon a main deck, and Fig. 27 the same area furnished with lamps upon this divided system. Ship return connections are used throughout.

This excellent system may always be carried out when there are two or more dynamos, and even with accumulators. In the case of the starboard and port steaming lights, each lantern carries two or

more lamps. In some cases the lamps are fed from

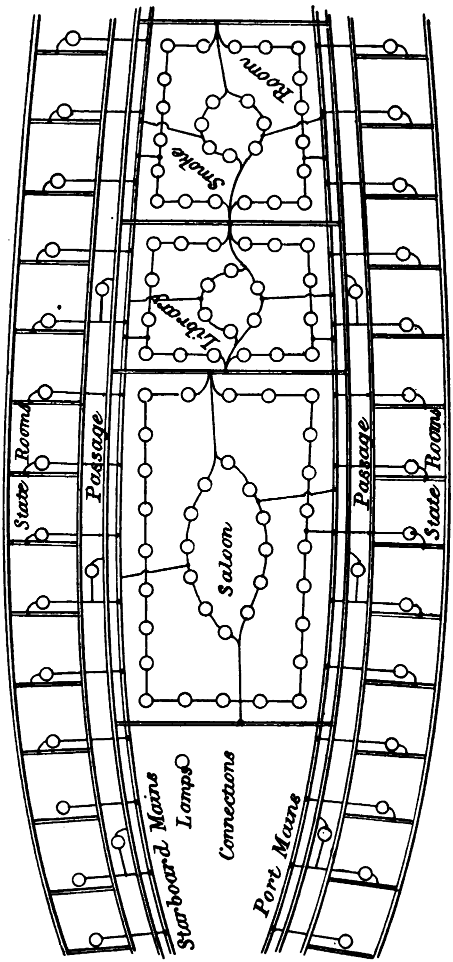


Fig. 27.—Plan of Wiring Passengers' Upper Deck of an Atlantic Liner.

separate circuits, with a common return. Thus, if

one lamp should fail, the other would maintain the light. The same system may be carried out in the case of bow and mast-head lights. It only necessitates the use of a twin cable, the return being made through the ship. Even in the case of binnacle lamps, the twin system should be observed, but full details of the *screened compass lamps* will be given further on.

Distribution of the Mains.—Mains should never be carried either longitudinally or transversely of a ship at a low level, except, perhaps, in the case of a warship. The reason for this is that in the event of collision they may be both damaged and immersed in water, and so put the ship in darkness. Arrangements should be made for carrying the mains to their respective areas just under the main deck. The particular course they should traverse depends altogether upon the build of the vessel and the arrangement of bulkheads and other partitions. Assuming that the dynamo-room is amidships the mains will be brought up and stretch fore and aft. The two independent sets are to be kept well upon the port and starboard sides of a line running longitudinally through the centre of the ship. As these mains cross the various separate compartments of the ship, the branches intended to feed the lamps there are forked down into them. In this way, while the mains are well protected from water from above, they are safe from risk of flooding below. The main supply is maintained from above. Deck-houses are fed from the mains by branches forked upwards.

The Piercing of Bulkheads.—At so high a level this is not open to the objections urged against it at a lower level. As a rule, if a bulkhead is required to maintain its watertight character as high as the

main-deck, it will not be objectionable to run cables through it at the highest level. The aperture is made watertight, if desired, by means of a pair of *stuffing glands*, Fig. 28, exactly similar to the stuffing boxes fitted upon the piston-rods of steam-cylinders. There is a gland for each side of the bulkhead, *a*, *a*. The hole drilled through the bulkhead is sufficiently large to

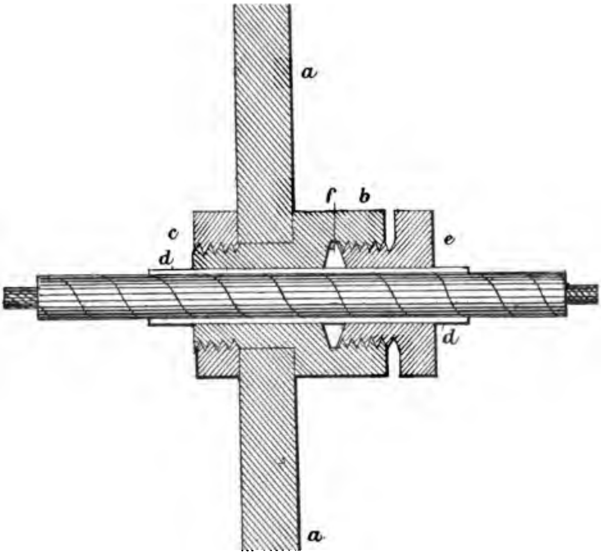


Fig. 28.—Bulkhead Stuffing-Box for Cable.

freely accommodate the male screw, *b*, which is long enough to engage the boss *c*, upon the other side. Vulcanised washers maintain the watertightness of the whole. The bore through the glands is made wide enough to receive the cable and an additional bit of vulcanized tubing, *d*, slipped over it. In this way the insulation of the cable is not exposed to the metallic touch of the glands. The stuffing-boxes

may be served with cotton or other stuffing, *e, f*. The result is a perfectly tight joint, capable of withstanding any pressure.

Ordinarily, when a main is carried through a bulkhead, it is not necessary to provide so elaborate an arrangement as that described above. A porcelain tube is frequently used, or a bit of thick vulcanised tubing, which is probably better. The tubing fits tightly upon the main. If it cannot slip in whole, it may be split longitudinally. The hole drilled in the iron is reamed out smooth to receive the tubing and cable, making a watertight joint there. Excellent as these arrangements undoubtedly are, they do not satisfy some. It is the opinion of some ship's electricians of experience that the best *bulkhead plugs* are made from crocus or cherry-wood, boiled in liquefied paraffin wax.

Ship Connection—Single-Wire System.—The connection between the dynamo and the shell of the vessel is a matter that calls for some little consideration. A very ordinary practice has been to connect the leading wire feeding the lamps to the *positive* (or "feeding") terminal of the machine, and to put the negative terminal in connection with the ship's metal. This arrangement works satisfactorily *per se*, but complaints soon began to be made that the return connections from lamps began to be subjec to *electrolytic action*, and became corroded away. Thus, it is conceivable that if damp should find its way around one of the screws or "return plugs" to which the negative pole of the lamp leads, there would be a constant tendency to make the brass plug or screw act the part of an anode in an electroplating bath. It would become electropositive to the iron, and it would

gradually dissolve away, the copper and zinc composing it being deposited upon the adjacent iron.

It is not to be assumed that an iron screw would withstand this electrolytic action in the presence of salt water. And indeed if we assume that the current were made to flow from the ship to the wire, or the exact reverse of the usual method, the action would probably still go on. There would still be a tendency to set up electrolytic action in the presence of such an electrolyte as salt water, the disengaged iron being deposited upon the brass screw. The "positive earth" system has not, however, had so extended a trial as to enable a just conclusion being arrived at. It is sufficiently clear that, so long as salt water remains around an electrical connection composed of *two dissimilar metals* there will be electrolytic action from one to the other, depending solely upon the direction of the current.

The natural impulse of an electrician is to connect the *leading* or *insulated* wire to the positive pole of the dynamo. No valid reason can be given for this, other than the mere assumption that the current flows *from* this terminal. But the arrangement is found to serve the lamps equally well whether it be negative or positive in connection with the leading wire. It is unquestionable that a large proportion of ship's electricians prefer at the present time to work from the negative terminal, after a trial of the opposite. Similarly, 90 per cent. of the ship's electricians prefer the single-wire system after a trial of the double system. The balance of practicability appears equal in respect to the negative or positive leading wire, but on the whole it would appear preferable to work from the positive terminal, and to prevent the

electrolytic action on return contacts by means of an insulating varnish, which will effectually stop off the contact of moisture.*

The "Ship Contact" Dynamo and Lamps.—In the case of the dynamo, particular care should be taken to insure that the connection is "good." It is not merely sufficient to join up to any neighbouring tie or girder. Such tie or girder may be in very indifferent connection with the shell of the vessel. As a rule all main connections should be made to bulkheads or the main girders of decks, if not to the shell of the side. The connection should be adjacent to the dynamo. It should consist of a gun-metal receiver, bolted with a clean surface to the metal, generally formed as in Fig. 29. The receiving eye should have at least two pinching bolts of large size to fasten the end of the piece of cable used. The extremity of the connecting piece of cable should be stripped of its insulating covering for several inches and passed entirely *through* the connecting eye. A blind eye is not to be recommended.

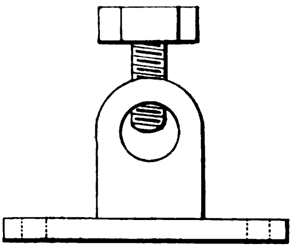


Fig. 29.—Ship Return Connector.

It is impossible to be assured that the cable is well home; if, however, it passes through the eye, the connection may be made doubly sure by burring over the projecting end. It is the common practice to use *black* cable for this connection. *Red* is used for leading mains, black implies negative or "return."

* Successful instances of negative leading wire working are the steamships *Isla de Luzon*, *Santa Domingo*, and *Isla de Mandanao* wired at Liverpool, and owned by the Spanish Shipping Company.

But when the return is actually through the mains, then if negative is to be indicated by black, the ship connection becomes *Red* and that to the mains *Black*. It is a general rule to paint the negative terminal of a dynamo or an accumulator black. The same rule holds with instruments that are so constructed as to require the electrical flow through them in one direction only. A black terminal upon an instrument means that the wire leading from the black terminal of an electrical source should be connected thereto.

With regard to the *lamp and branch return studs*, they generally consist of brass screws, to which the return wires are soldered. In some cases the screws assume the form of studs, having pinch screws and eyes for receiving the wire. This is very convenient, but as pinch screws have a habit of working loose, bad contact may shortly after instalment occur at such points. It is much better to solder the wire to the screw, wrapping it well around the stem first. Before a return wire is connected to a ship stud it should have an elasticity spiral made upon it by twisting the end a few turns around a metal rod. This will give a certain springiness to the wire, and obviate its snapping short off by reason of any vibration between adjacent woodwork and the shell of the vessel proper. The smallest size of screw contact that should be used is $\frac{1}{4}$ inch diameter, Whitworth standard. This size will suffice for a few lamps. For a branch wire carrying several lamps, a $\frac{3}{8}$ inch screw should be used. These connections, when complete, should be well coated with asphaltum varnish.

Single-Wire System—Casings for Mains.—Mains are carried in wooden casings. These are screwed

generally to adjacent woodwork. But numerous instances arise when main casings must be attached to girders, ties, rails, bulkheads, and other parts of the internal structure. This calls for the drilling of screw-holes in such iron work. The breast high-speed drill brace will be found convenient for such work. The position of the casing having been chalked off, the screw-holes are marked at distances of from one to two feet, by means of a centre punch. The holes are quickly made by means of a twist drill. They are afterwards tapped to receive ¼ Whitworth screws.

The casings consist of thick channeled laths, preferably of pitch-pine, because this wood being highly resinous, prevents the intrusion of wet from behind. The casing has a single channel, deep enough to receive the cable, which sinks in the casing until flush with its surface. The channel is made full large for the main. This allows of the latter being bedded in putty in the channel. The putty should be laid in the channel first, and the cable pressed upon it, care being taken that the cable is *entirely surrounded* by the putty. If the bedding of putty be well done, soft wood casings may in most cases be made to serve. But all casings should be painted with a lead paint before being put up. The casing is finished by screwing upon it a thin wood cover. Single channel casings are now an article of commerce. Those for ship work must be free from flaws, as cracks or loose knots. The wood base behind the back of the channel should be at least ¼ in. in thickness. Holes for hanging should be made with the drill brace, a good distance away from the channel. This point frequently leads

to trouble. Wet may accumulate behind a casing; it cannot penetrate the casing itself, but it easily creeps around the screw, and finds a simple path through the unprotected wood to the interior. It is preferable to hang casings on ironwork, not by means of screws through the casing, but by the aid of square iron cleats or clamps. These embrace the whole of the casing, either below or above the cover; the latter is preferable, but it involves the taking off of the supports when it is desired to remove the cover for any future purpose. The clamps or cleats may be single or double screwed, as the case may require. For mains of considerable section the casings must be firmly fastened to both wood and ironwork. After completion the whole usually receives a coating of the white lead paint so much used aboard ship.

Casing to be avoided when practicable.—Well-insulated cable for mains require no casing, when it can be run upon woodwork that always remains dry, and where it will be free from mechanical injury. The advantages of this will be easily understood when it is considered that open wiring permits of the detection of a fault at once, whereas in the case of covered wires the locating of a fault is frequently a tedious process. Open wiring may be carried on under decks, where there is sufficient woodwork to warrant it. Casing may be dispensed with in the working quarter of the ship, in store-rooms, in the course of alley ways, and so on. The wires are attached to the woodwork by means of cleats, forming loops over the wire at regular intervals, with screws into the woodwork.

Concealed Wiring.—Whenever practicable concealed wiring should not be put into a ship. It may be in place in a mansion or hotel, but it is out of place in

a ship. The source of the main and branches should be *accessible at all points*, and this without the necessity to damage a square inch of any ornamental work. The temptation to conceal the mains and branches behind the ornamental woodwork of a saloon or library may be very strong, but it is not a necessity if a little ingenuity be exercised. There are always cornices above, and spaces beneath couches below, in the course of which wires may be led, either in cases or simply cleated. It must be borne in mind that it is not the present, but the *future* of the installation that has to be considered. Throughout every part liable to be exposed to wet or moisture arising from any cause, casings should generally be used, but they should cease when the sight of a bare cable would not be objectionable, and where the place is likely to be dry enough to permit of cleat wiring. Casings, mouldings, and small cornices can be made in such variety of design, and in such materials, that almost any style of ornamentation can be matched, and a casing put in that will not only not detract from the pleasing effect, but add thereto.

When wires are run behind wainscot, or between a real roof and an ornamental ceiling, conditions frequently occurring in the saloon or state-room quarters, they must be carefully hauled taut, and well cleated. This is a very objectionable manner of wiring, even in houses, but it is especially so aboard a ship. Care must be taken if wires are run behind woodwork that they do not come near metal. It is indeed almost impossible in a ship to avoid touching metal in this kind of work, but notwithstanding the difficulties and dangers of it,

ignorant builders will sometimes insist upon concealed wiring. If wiring must be concealed it should be done carefully in casings before the cabinet-makers put up a foot of their woodwork.

Numbering of the Circuits.—The men who wire a ship are not probably those who will have the installation under their charge. It is thus plain that, although the wiremen may know very well where each main and branch leads to, the system may be a sealed book to a strange engineer about to run the electrical machinery. Hence it becomes an important matter to indicate upon each main its number. This is most conveniently done at junction-boxes, which should be clearly stamped with the number of the circuit, and, if possible, with an indication of the direction in which it leads. Thus an arrow, stamped upon a casing or junction-box will suffice to show, with the number, the starting-place and the probable termination of that lead. Small enamelled tablets with the words, "Circuit, No. ," are now coming into use for this purpose.

Distributing Closets.—Where several leads arrive at an area to be lighted there should be situated a locker, and within this locker the joints of all adjacent branch-wires should be made. The cut-outs should also be included. It is bad practice to spread a number of cut-outs and joints apart. They should be, as much as possible, brought together, and in one distributing-box from a general starting-point.

The advantage of this is that all junctions are at once brought into view; so are all the fuses. One glance thus suffices to inform the electrician as to the cause of a fault upon any branch. It should, indeed, be the rule to have no joints of any importance, save

in one of the several closets. Lockers for this purpose need only be a few inches in depth, and can easily be arranged for in the most crowded ship. In wiring a large ship it is most important to arrange for two independent sets of circuits. These should be known as the *port* and *starboard* circuits respectively. The mains for these should be kept well apart, so as to occupy either side of the ship. Each set of mains must have its own distributing closets. In a fair-sized vessel six distributing points will generally suffice. These will be situated somewhat as follows :—

Port distributing-closets: one for forward accommodation, one for amidships, and one for after accommodation.

Starboard closets will be exactly similar, and will send out branches for one-half the lights in each important department, already partly served from the port closets.

Unimportant lights, as alley-ways, state-rooms, stores, and so on, may be served from one side only. That is, each side takes its own detail lighting, but the general lighting in saloons, bars, smoke-rooms, libraries, steerages, galley, and pantries, should all be served on the double system.

Number of Lights upon One Circuit.—This is a question that depends for its solution very much upon the circumstances of each case. Since we are in the present instance endeavouring to separate the general lighting into two divisions, the number of lamps required for half the lighting upon a given area may not amount to 50. This number is generally regarded as a safe limit, not to be exceeded, upon a single circuit in house-wiring. It is, however, frequently exceeded in ship-lighting, as

will be seen by reference to the scheme of wiring set forth at page 161.

The word circuit, however, in the ordinary kind of ship-wiring has not the same significance that it bears to house-wiring. In the latter case a pair of wires, leading wire and return, are taken from the switch-board, and generally traverse a great deal of space throughout the building, feeding lamps in single pàrallel at different points. The extreme ends of these two main wires would be dead insulated ends, or they might possibly supply one lamp there. These two wires with their bridging lamps would be regarded as one circuit. In such work fifty lamps is seldom exceeded. But in single wiring aboard ship the case is very different. Here a main leads from the large switch-board to the centre of its lighting area. At this point there is placed a distributing locker. From this locker branch wires are forked away to different parts of the area to be supplied.

These may run close along ironwork communicating with the ship's shell, in which case very short return wires suffice to carry the current to "return" from each lamp. But there may be lines of lamps away from any "return" metal. In this case, these lines would be served by a return wire, quite uninsulated, running along their course, and communicating with the ship's shell at a convenient place.

Thus an electrolier (rarely used aboard ship) having many lights, would have communicating with all of its lamps a single naked return wire, the centre or end of which would send off another branch to the nearest ironwork. The lamps would, upon the

other side or terminal, be fed by an insulated wire, the centre of which would join with a branch direct from the main.

This is really the *Tree* or *Stem and Branch* system of wiring, with the slight difference that the twigs are not forked out in pairs as in house-wiring. One main matter must be borne in mind in wiring a ship. We are working upon the parallel system with a single lamp across the wires, or single parallel. It will not serve to put two or more lamps in series across the wires. There must throughout all the ramifications, be a clear single path from the main through each single lamp to the return.

Lamps of different Candle-powers working together.— Reference to page 160 will show that upon circuit No. 1 there are three 50 candle-power lamps, working on a circuit feeding 16 candle-power lamps. It is obvious that since the electro-motive force of the dynamo is the usual 110 volts, allowing 100 volts for the lamps, and the remainder to be wasted upon resistance of leads, the 50 candle-power lamps must take only 100 volts also. It is usual to allow about 60 watts for each 16 candle-power lamp on such a circuit. The only difference between the two cases would be that the 50 candle-power lamps would take, at the same rates of current to light, rather over 180 watts of current. Now in estimating for the sizes of the mains and branches, it is the *current* that must be considered before anything else. It must be known what class of lamps and how many of each are to be run upon each branch.

The current in watts that will be taken by these lamps must be added together to get the total watts required to flow in that circuit. If this be done, and

wires large enough be selected to keep down the loss of volts in the usual limit of 2·55 volts for every 100 yards of leading wire (at 1,000 ampères per square inch), there will be no difficulty in burning different candle-power lamps upon one circuit. But these lamps must, without exception, be 100 volt lamps (we are supposed to be working at 100 volts), otherwise they will not burn. Each 50 candle-power lamp will thus merely consume as much as three or four 16 candle-power lamps, according to the construction of the carbon in the lamp. The actual consumption of current depends upon the watts per candle-power taken by the particular lamp in question. This varies greatly in different makes, from 4 watts per candle for lamps up to ·9 of an ampère, and 3·5 watts per candle for those taking more than ·9 of an ampère. It is usual for the maker of the lamp to indicate upon its stem the particulars of its supply, as the voltage, and in some instances the watts per candle, and total current taken at a safe degree of incandescence.

It will be quite clear from the above considerations that it would be impracticable to work 50 volt lamps upon a 100 volt circuit, but that it is quite easy to work 8, 16, 20, and 50 candle-power lamps upon such a circuit, provided that the lamps are furnished with filaments taking 100 volts. Indeed it is very usual to employ 8 candle-power lamps in berths and small spaces. They are frequently sufficiently large for such purposes. It may be further remarked that in many cases two 8 candle-power lamps will light a space much more effectually than one 16 candle-power lamp, owing to imperfect diffusion of the light. In this way low candle-power lamps are found very useful on shipboard.

Jointing.

The connections between main wires and branches, and between the latter and twigs or sub-branches, forms a most important part of the installation. No portion of the work calls for so much *conscientious care* as the jointing. It is a class of work that is not exposed to view, and is, therefore, very often performed in a perfunctory manner. Since the success or failure of a system of electric lighting must largely depend upon the integrity of the system of conductors, and upon the completeness and efficiency of the insulation protecting them, it will be obvious that the connecting part of the work must be well done, the more because it is not merely a mechanical joint that is wanted. It is not merely an electrical contact, nor is it simply a completeness of insulation, but it implies all three of these in perfection, mechanically for strength, electrically for perfect continuity, and sufficient insulation to insure that the joint is at least equal to the rest of the cable in that respect.

If jointing in a careful manner is an essential thing in a house it is still more important in a ship. While a house remains dry, no part of a ship is quite protected from damp or water. If no water obtains access to wires or joints, the mere changes of temperature to which a ship is subject cause walls to "sweat" and moisture to cover all surfaces. In the case of a ship sailing between European ports and America, temperature may be as low as zero while keeping a northerly course, but in a few hours the vessel enters the Gulf Stream, and the frigid condition is exchanged for the balmy breezes of midsummer. Such changes cause, upon ironwork especially, a copious condensation of

moisture, which for some time to come may trouble the electrician by its baneful effect upon the insulation of the whole system of conductors. We have before alluded to this subject, and it may appear that too much stress is being laid upon the question of insulation, but to those who have worked an installation aboard ship our inferences concerning these difficulties will be acknowledged to be rather insufficient than otherwise.

A perfect joint consists in three matters: 1st, a mechanical connection between the wires so strong that when strain is put upon the joint the wire is as likely to break as the joint: 2nd, an electrical connection so perfect that its resistance to the current is even smaller than that of the general run of the wire or cable; and, 3rd, an insulation joint so perfect that, mechanically and electrically, it is at least as effectual as the general unbroken insulation protecting the wires. These three conditions can be met in every respect. But it must be understood that jointing is a business to be conducted upon a set system, and not only faithful work, but knowledge and skill are required in a good workman.

Joint Solders and Fluxes.

A few words concerning the materials used in soldering the joints, and of the process itself as applied to electrical purposes, may prove useful to the reader.

When a perfectly clean surface of copper is moistened with a weak solution of chloride of zinc, it is ready for tinning or soldering. The solder itself, consisting of tin alloyed with lead, is of that kind commonly used by workers in tinplate. It is

most conveniently applied to the article by the aid of a soldering "iron," which, however, must be a tapering and pointed piece of copper, sufficiently heavy to retain heat for some time. This "iron" is furnished with a stem and a wooden handle. Before the iron can be used its point must itself be "tinned." This is done by heating it *nearly* to redness, and quickly filing clean surfaces upon the sides of the point. The clean surface is then quickly rubbed upon a piece of solder, previously wetted with the soldering fluid. If the copper be free from oxidation, it will become coated with a layer of the tin solder. If failure to tin the point be encountered it will invariably be due to one of two causes. The filed surface has not been applied to the solder quickly enough before it re-oxidized, or the iron is too cold. If the iron be made too hot, it will be impossible to tin it, and in using soldering irons care is to be taken never to exceed a heat sufficient to freely melt the solder, otherwise the tin will become burnt off the point and the process will have to be repeated. The tinning, or soldering of a surface, is effected by merely touching it or rubbing upon it, the prepared soldering iron. If sufficient solder does not cling to the iron, its application to the solder is repeated. In practice the jointer, holding the solder in his left hand fuses off a drop of it with the iron held in the right, and applies this drop to his work. The solder will readily flow or "run" wherever there is a clean surface, coated with the flux. Without flux it will neither "take" nor flow upon the surface. The iron must be heated sufficiently.

Regarding the question of fluxes, which is a greatly contested one amongst wiremen, there can be no

doubt that for jointing, resin powdered fine is the best flux to insure the integrity of the joint. But the use of resin necessitates extreme cleanliness of the surfaces, and some skill in applying the solder. The latter does not tend to flow or "run" so freely upon a resin flux as upon a fluid one. But as fluid is generally employed it is a questionable advantage. The soldering fluid in general use is made by dissolving chips of zinc in muriatic acid until the latter is exhausted. If this be left upon a joint that part will never dry, because the chloride of zinc is a deliquescent salt, and a state of rottenness is set up. All such joints should be washed, and the fluid used very sparingly. There can be no doubt that resin joints, carefully made, are the best.

Preparation for Jointing.—Wires to be connected together electrically must have the portions over which the joint is to extend denuded of all covering. The copper must be perfectly free from rubber or oxide—it must be made bright by scraping or friction with emery-cloth. Since the insulating covering will be made to lap again over the joint, some care will have to be used in removing it. In the case of windings of cotton, hemp or tapes, they are merely cut through and unwound the required distance, but not cut off. In the case of rubber, vulcanised upon the wire, it will generally form a tube simply and cannot be unwound until it is divided in the middle of the space and a spiral cut made in it with the insulation knife. This if well done will form the rubber into a ribbon, wound spirally upon the wire. The ribbon is not to be cut away. These preparations apply to all wires, whether they be T-joints or end-to-end splices.

Longitudinal Joints in a Common Single Wire.—

Remove the insulation from two inches of each end. With the file make a scarf or switch upon either end, so that upon placing one upon the other they will form a joint not larger than the diameter of the wire, *a*, Fig. 30. Tin both ends with the soldering-iron. Place them together and heat gently over the spirit-lamp. They will readily fuse together, *b*. They may be kept in position by holding one end in each hand. When cool dress down with the file. Wind a close spiral of tinned copper binding wire tightly around

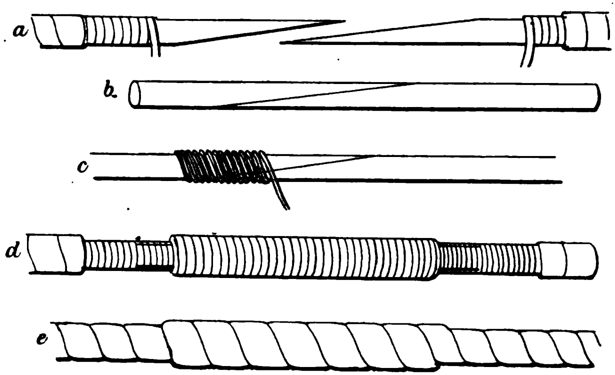


Fig. 30.—Spliced Parallel Conductor Joint.

the joint, entirely covering it, *c*. Moisten with soldering fluid and sweat the whole together with fresh solder upon the iron. Again dress with the file, and see that the joint is quite dry. If any moisture remains it will set up corrosion. If necessary, wash and dry the joint. This makes a very neat joint, but it is not very strong against lengthwise pull. Varnish with rubber varnish and proceed to replace the rubber insulation as neatly and closely as possible. Varnish again and apply a winding of narrow pure rubber tape.

Soften this above the lamp, and press closely together with the fingers. This should form a complete rubber sheath. Varnish again and over all wind the original tape, varnishing freely. The whole when done should form a round joint, *d* and *e*, but little larger in diameter than the insulated wire. It should withstand immersion in water for any length of time.

The Insulation Joint may be made differently. The original rubber may be entirely removed, over the joint, which should be kept warm and dry with two or three close layers of fine rubber tape, applying the vulcanising solution between each. Over all a layer of rubber varnish. Finally the original tape, or a winding of new tape extending beyond the limits of the joint. In either case the chief points requiring attention are those where the new insulation joins the old. If there be not perfect contact here, the joint will be faulty. Combination of new and old is the chief point to be obtained.

Soft Insulation Joint.—Soft insulation consists of pure india-rubber, unvulcanised. It forms a very perfect protection, electrically, but it is weak in a mechanical sense. It might be well protected by braiding or windings of tape, but it has another defect in respect of electric-lighting work. Unvulcanised rubber is easily melted at a low temperature. The heat imparted by a full electric-lighting current, when the density rises as high as 2,000 ampères to the square inch, would perceptibly soften the rubber. For this reason the unvulcanised variety is not often used. But it is perfectly admissible in cases where the current density is maintained at a low value.

The nature of the insulation joint will depend upon

the metallic joint to some extent, but assuming that the original rubber has not been cut off, and that a splice-joint has been made, the rubber is treated as follows :—

Dry and warm the metallic joint. Proceed to stretch down the soft rubber from either end, working it closely and equally around the joint, until both ends unite, forming a perfect coating. This latter junction may require the application of a hot iron to run one end of the rubber into the other. Allow the whole to cool. Apply a coat of Chatterton's compound. Warm a narrow strip of pure rubber tissue. Fasten the end to the joint, holding it over the lamp, and proceed to wind it closely around the middle of the joint. If this is well done, it will form a solid rubber ring around the middle. Keeping the rubber soft, work it lengthwise of the middle to either end, and tool it into complete connection with the original insulation. It should be finished round and smooth, the wire occupying the middle. If the wire be protected by tape or braiding, let this be replaced, and the whole well varnished. This joint should stand long immersion in water.

Note as to Cleanliness.—In working soft rubber, as a coating or as tissue, particular care must be taken that the hands are perfectly clean, and free from perspiration. Any impurity coming in contact with rubber will spoil the joint, and may cause it to "rot," and become soft and useless. Wiping the fingers, after washing, with wood naphtha, or methylated spirit, is a useful precaution.

Another Metallic Joint.—Clear away the insulation for two inches from either end. Clean the copper. Place the two ends together parallel, so that they

overlap the full length. Grip tight at one end with hand-vice. With pliers proceed to twist one end over the other alternately, until a close, tight spiral is obtained. This takes a little practice. The joint is completed by releasing the hand-vice, and transferring it to the twisted end. The unfinished part may then be twisted. The joint thus forms two spirals, similar to a pair of corkscrews worked into one another. The tightness of the joint is a test of its strength. Finish by moistening sparingly with soldering fluid, and sweating with solder run in with the iron. Dress off smooth, and cover with the insulation joint.

Another and simpler way to form a spiral joint, but which is more clumsy, is as follows:—

Place the cleaned ends across each other near to the insulation. Grip with the hand-vice or pliers. Proceed to twist the two projecting ends together until a close spiral, an inch in length, is obtained. Cut off the remaining ends. Bend the spiral carefully parallel with the wire, and solder together. This is suitable for very thin wires.

Joint in a Heavy Wire.—A very strong and efficient joint may be made as follows. It is suitable for wires liable to longitudinal strain. Clear away insulation from either end for three inches. Clean the wire, bend each extremity sharply at a right angle, half an inch from the end. Place the wires parallel together, with the bend upon each near to the insulation of the other. Hold with hand-vice. Apply a length of binding wire. Whip it around the single wire at one end a few times. Extend the wrapping over the twin wires until a finish is made at the insulation at the other end, again upon the single

wire. Solder the whole together. Cut off the ends of the wires projecting beyond the wrapping, and finish with the file. Wash and dry the joint. Warm over the spirit-lamp, and apply a soft length of pure rubber tape. Work and tool this carefully over the whole joint, and over the original covering. Replace, as far as practicable, the old covering, with the aid of coats of varnish. Allow one coat to dry before applying another. Finish with the old exterior tape, and a final wrapping of new tape, carried well over the ends of the joint. Use rubber varnish between, and shellac varnish as a finish. The joint should withstand continued immersion in water.

Longitudinal Joint in a Cable.—Conductor of seven strands. Clear the insulation for three inches from either end. Bend up the six outer wires of each end at right angles sufficiently, and *cut out* the central one from either end. Bring the wires of one end against those of the other, so that they intermix, and form twelve wires interlaced. Grip near the middle with two pairs of gas pliers. Twist one hand to the right, and the other to the left. This will form a longitudinal twist between the wires. Continue twisting tightly until the ends are reached, It calls for some skill to make a good joint in this way, but when accomplished it is the neatest that can be made in a stranded conductor. The pliers must be held tightly throughout. If the joint is *well drawn together*, the cut ends of the central wires should meet. In a cable having fourteen strands, the centre consists of four wires. All of these should be cut out, and the ends filed flat, so that when they come together, there will be intimate contact between the two cores. The twisting of the exterior wires must be especially

perfect in the case of cables having large cores cut out in this way, otherwise the cores will not come together. The whole of the current will fall to be carried by the exterior envelope of wires, and overheating at the joint may be set up. Fig. 31 shows a branching splice suitable for heavy wires, and intended to be overwound and soldered. Fig. 32 exhibits the Britannia joint, invented by Mr. Latimer Clark.

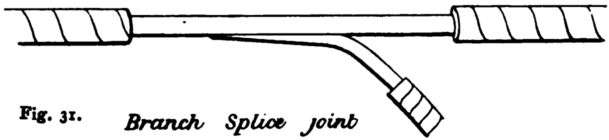


Fig. 31. *Branch Splice joint*

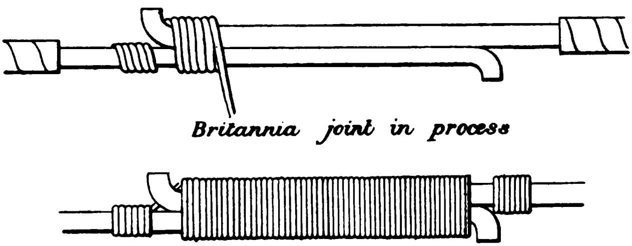


Fig. 32. *Britannia joint completed*

In a cable of nineteen strands, the core will consist of seven wires. It must be cut away quite flat, and well butted together. After the joint is twisted or drawn together as tightly as possible, it is moistened with fluid, and thoroughly soldered, insuring that the latter shall penetrate to the core, and make good the connection there. When the core is large, as in a fourteen or a nineteen-strand cable, it is well to apply fluid to both ends of it *before* twisting up the

enveloping wires. This will insure against the risk that the fluid may not flow into the interior. *Resin* is *better* for this sweating process than *fluid*. The latter is apt to be used too freely, to insure its flow, and some of it is apt to remain open, or within the joint. If this occur, it will set up electrolytic action, which will in time make the joint rotten. This kind of joint, when well made, is the neatest, and probably the most effectual yet tried, but it has the disadvantage that it is not so strong against longitudinal pull as a more clumsy form of connection.

Extra-strong Longitudinal Joint in a Cable.—This connection is made somewhat similarly to the last. The ends are cleaned, enveloping wires bent up, and core cut out. But at this stage each opposing pair of wires is to be *twisted together separately*. Then the whole is twisted together as before. This makes a thicker joint than the above, but it has the advantage of being very strong. It must be trimmed down smoothly after soldering, so that no sharp projecting points remain that might pierce the insulation. All of these joints should be served, after washing, if fluid has been used, with a preliminary coating of pure rubber, applied hot.

T-Joints.—These are used in cases of tapping a main wire for supply to a branch. It is a kind of joint of which a great many have to be made at every installation. As generally done it is very simple and effective. The tapping point upon the main having been determined, the insulation is carefully cut through in two places, around the main, an inch apart. The measurer exercises great care, in using his knife, *not to notch* the main wire. The one inch length of insulating material is next slit longitudually

and removed. The main wire is scraped clean. Insulation is removed from a few inches of the branch wire, and that also cleaned. The branch wire is laid across the main, up to the point when insulation commences, and to the extreme left of the one-inch space. The branch wire end is now twisted in a close spiral around the main, and when it has filled the space, the end is cut off close. The next step is soldering, then trimming smooth. The insulation commences by the application of warmed rubber tissue, in several layers, with rubber varnish. The

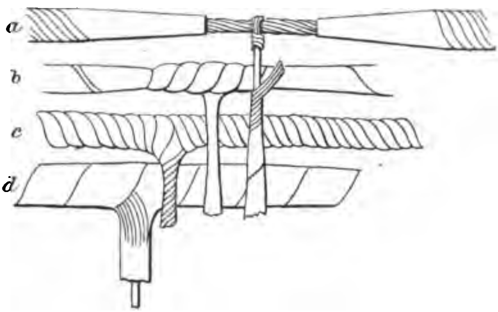


Fig. 33.—Details of a T-Joint.

whole is incorporated together, and must extend beyond the original gaps. The rubber is tooled down at the junctions. A winding or two of waterproof tape, with varnish, completes the joint, which must be capable of withstanding immersion in water without leakage of current. Fig. 33 shows a still more common method of connecting branches.

Cable and Single-Wire Parallel Joint.—The neatest way to continue a stranded conductor along a single wire is to remove the core of the former. If the cable be a seven-wire one, the central wire is cut out

for about three inches, and the single wire takes its place. If the cable be a 19-wire one, and the single conductor be of considerable thickness, it is usual to cut away 3 or 4 inches of the whole of the core—7 wires—leaving only the enveloping wires. These are twisted tightly around the wire, and the whole carefully soldered through. In making such a joint, the end of the core where cut off should be flat. The inserted wire should have a flat end to butt against, and should be previously tinned. Such joints are not very strong mechanically, and must not be subjected to much strain. The joint may be made mechanically strong by the expedient of bending the end of the single wire sharply at a right angle, and

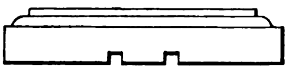


Fig. 34.—Double Wire Wood Cleat.

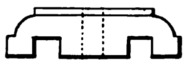


Fig. 35.—Double Cleat or Moulding.

thrusting this projection between two strands of the cable. It is made tight by close twisting of the enveloping wires. This insures that the central wire shall not be easily pulled out, but it makes but a clumsy joint.

Brass Connections.—The use of brass connections, with mere set-screws to pinch the conductors into contact, cannot be too strongly condemned in the case of permanent work. They are made in an endless variety of styles for temporary connecting, for which purpose only they are admirably adapted.

Wood Cleats.—Those are made in a variety of patterns, generally for double wiring as shown in Figs. 34 and 35. Casings, Fig. 36, are made single and double.

Porcelain Cleats.—These are useful for internal or room wiring and in turning corners. Fig. 35 represents the form in which the double-wire pattern is made.

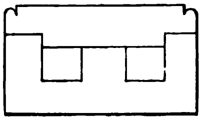


Fig. 36.—Double Wire Casing with Cover.

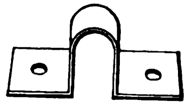


Fig. 37.—Saddle for Stranded Conductor.

Brass and Leather Saddles.—Brass saddles, as Fig. 37, are seldom admissible, except for screwing to dry wood. Leather is more safe, as it is not liable to chafe through the insulation.

Joint Boxes.—A convenient form of straight joint box is shown in Fig. 38. It consists of a tube split in two halves, and arranged for screwing together. The diameter is intended to fit the cable nearly, which is rendered watertight by a packing of putty. A similar joint box, adapted for a double T-joint, is shown in Fig. 39. These boxes are very useful for protecting junctions liable to be exposed to the weather. They are procurable screwed to fit gas-pipe, through which conductors are sometimes passed for protection. They should be cast in brass when small. This gas-pipe protection is almost always used in both boiler and

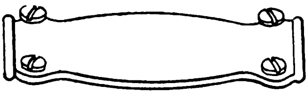


Fig. 38.—Longitudinal Joint Box.

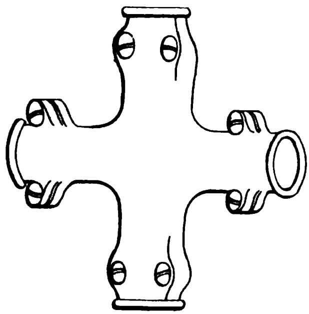


Fig. 39.—Two-way Joint Box.

engine-rooms, and is especially required in the former. Such boxes are especially useful for protecting joints in lead-covered cable. Lead-protected cable joints should be protected by the lead itself, but it is seldom that a T-joint, made in such a conductor, is so finished that a cover of some kind can be dispensed with. This is still more true of the double T-joint, or other more complex forms, rendering the making good of the lead sheath a rather difficult matter.

CHAPTER VII.

LAMPS, SWITCHES, AND CUT-OUTS.

THE main cut-outs at the base of the chief conductors having already been spoken of (page 149), we have now to consider the appliances for the same purpose adapted to the system of distribution practically at the ends of the mains. In some cases doubtless the use of a common fuse-board, placed in a distributing cupboard, may be made to serve as a general safety device, feeding several branches or sub-mains. But experience has shown that the use of watertight cases for sub-main cut-outs is extremely advisable. It is not always that a cut-out should be placed in a distributing box; in many cases it has to occupy a position exposed to the risks of being covered with sea water, or at least open to damp atmospheres. It is in such places that watertight cases should be provided to completely protect the branches and fuses of sub-mains. In the case of single wiring this arrangement will be very simple. A cast-iron oblong box is generally used. Watertight plugs, through which the conductors run watertight also, occupy either end of the box. There are as many plugs as there are sub-mains to protect. The base or inside of the box is preferably made of slate, having brass connecting pieces attached to its upper surface by screws from beneath. These connections

receive at one end the extremities of the sub-mains, and between them they carry the fusible slips. These latter are fastened down preferably by butterfly nuts, so that no spanners or wrenchers need be sent for, when a fuse has to be inserted without delay. The cover of the box closes watertight upon an edging of vulcanised rubber or other approved means. The box is made to open easily so that no time may be lost in ascertaining whether (and which of) the fuses have given out upon the occurrence of any accident.

Position for Cut-outs.—The main cut-outs at the dynamo switch-board are intended to carry a current just under what is estimated to *overheat the mains.* This current might be 100 ampères. If a thin branch were taken off such a main, and were not provided with a cut-out, the maximum current of the main, which might not perceptibly warm it, might fuse the thinner conductor, upon the occurrence of a short-circuit. Hence, *cut-outs should be placed at the base of all branches from the main.* Thus, it is impossible to safely dispense with two cut-outs between the dynamo and the lamps. *A multiplicity of cut-outs is a source of weakness* and loss, and even danger, but the main and sub-main cut-outs cannot be dispensed with. Cut-outs must similarly be placed upon all branches from main branches.

Cut-outs for Double Wiring on the Double-Wire System.—Cut-outs must be put to both leading and return wires. This may appear unnecessary, but it is really very important. A short-circuit may occur by the earthing of any wire just as readily as by contact between lead and return, and it is to the cut-out on the return wire that we must look for a severing of

that circuit in case of short-circuit to earth. As a matter of course the arrangements in the case of double wiring are of necessity complex, and it is almost a necessity in a passenger vessel to add thereto by placing a *switch cut-out* as one of the two. Thus, in case of having to replace a fuse there, it might be necessary, in the case of plain cut-outs, to switch off the whole of the main supply before the fuse could be replaced. But if a switch cut-out be used it will only be necessary to disturb the lights beyond the break.

Reduction of the Number of Metallic Contacts.—In order to reduce the number of contacts introduced by the cut-out system, an ingenious electrician will endeavour to solder or sweat in as many of the main and branch connections to cut-out blocks as practicable. A soldered connection is far more reliable than a set-screw connection. Connection by *metallic touch* cannot be superseded in the case of the fuse-slips themselves. Many persons object to sweated or soldered contacts, contending, and not without reason, that they render alterations difficult. It may be pointed out, however, that when alteration of circuit is probable in the near future, the binding-screw connections should be made with double set-screws.

A good deal has already been said regarding the material and so on of the fuses themselves. With regard to their shape it is impossible to say that any particular one is the best, but there can be no doubt that the ribbon-fuse is an excellent shape for practical purposes; it gives a good, broad contact, above and below, and is easily handled; it is, moreover, not liable to be cut across, damaged or broken by the pinching-screws. *The worst possible shape for a fuse wire is round.* The wire being soft, the set-screw, if

applied tightly, tends to break the wire in two, and the touch is far from satisfactory. If round wire must be used it should be made to form an eye or circle, to encircle the stem of the screw, so that a broad contact may be obtained. If placed in round-hole terminals, fuse-wire should have hard brass ends for insertion into the terminal.

Detached Branch Cut-outs.—As a general rule, small branches are more conveniently fitted with cut-outs detached from any distributing-point. It is not often practicable to arrange for given points of departure for minor branches, such as would be taken off to feed 20 lamps or less. The branches become so numerous that to save wire the cut-out must be placed by itself; and it is not always that it can be placed strictly at the base of the branch, owing to the starting-point from the main being in an inaccessible place, where it would be inconvenient to gain access to the cut-out. Endeavour must always be made in such cases to make the length of branch-wire between the main and the cut-out *thicker* than the branch itself. This will insure that upon heat being set up in the wire, the fuse will go before any excessive heat is generated in the connecting piece from cut-out to main.

Detached cut-outs are now produced in a variety of designs, and some of the forms, serving as ceiling plates or roses in rarer instances, are illustrated further on. They usually consist of a slate base, enamelled, carrying two blocks of gun-metal, one on either side of the middle. Each block is furnished with a receiving hole and screw, one for the branch to the main, the other for the branch to the lamps. The two blocks are connected across

by a fuse-wire, furnished with flat contact-plates, for reasons already fully explained. The slate (or other insulating material) base is pierced with holes through which are passed the two wires, and also with screw-holes, by means of which it is attached to any convenient woodwork in the course of the branch. Over all is placed a domed cover, fitting watertight into a groove in the base, and fastened with a screw. Such a branch cut-out may be adapted to feed any number of lamps, from one to 20, *according to the carrying capacity of the fuse-wire.*

Cut-out and Switch Combined.—In the case of ship-lighting, where a saloon, library, or steerage is lighted partially by a branch, it is usual to control all the lamps upon that wire by means of a single switch. In such case it is a great convenience to combine the switch with the cut-out, so that one base and set of connections may be made to serve for both. This device is known as a cut-out switch. It saves a great deal of connecting to employ a cut-out switch for all branches when a number of lights are run at once, or in other words are always turned on and off together.

Multiple Cut-out for Branches.—In many cases a number of small branches carrying from two to ten lamps may conveniently be forked out from one point in a pair of mains or from a leading wire only on the single system. When this can be done it allows of the whole of the cut-outs for these branches being assembled upon a single board. This arrangement saves much time to the attendant. He has the bases of several branch circuits at one point, instead of their being scattered over a large area, sometimes in isolated corners.

Multiple Wire Cut-outs.—When fuses are of considerable size, it is better to subdivide them than to employ a single large wire. Hence it has become the practice to make large cut-outs with several ribbons or wires. These possess the advantage of giving way and breaking the circuit with greater promptness than usually occurs when thick fuses are used.

Detached ten to fifty-ampère Fuses.—The very simple and effective form of cut-out represented in Fig. 40 is extensively used for single branches carrying any number of lamps. It consists of a slate base, carrying two blocks of gun-metal, each furnished with two clamping bolts for receiving the main connection, and a pair of clamping screws for attaching the fuse-plate to the blocks, across the gap as represented. The base may be fitted into a cast-iron box when required, and so rendered water-tight.

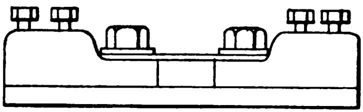


Fig. 40.—Ten to Fifty Ampère Cut-out.

What should a Cut-out Protect?—A very erroneous notion prevails that cut-outs are intended to protect the lamps from the danger of being broken by an excessive electro-motive force. This is not the true function of a cut-out. Its main object is to obviate the occurrence of a *dangerously-large current in any wire*, and thus to prevent entirely the risk of setting fire to woodwork by red-hot conductors. Cut-outs doubtless at times do protect incandescent lamps, but this is mainly incidental to the chief object.

Switches for Heavy Branches.—A branch carrying from twenty to fifty lamps or more, sometimes serves

one-half of a main saloon, wherein all the lights are turned on and off at one time. The individual lamps, in such cases, are not provided with switches. These would be generally inaccessible for use if they were fitted to each lamp. In such cases, which are very common aboard passenger steamers, the current is switched on and off by one main switch. This is not done in the dynamo-room. It would be inconvenient to cut off at the mains, which will probably be feeding numbers of stateroom lights, liable to be turned on at any time. Such heavy branch switches assume various forms. The "hatchet" switch, now extensively used, and represented in plan in Fig. 41, is admirably adapted for this purpose. It consists of a base of slate, or other insulating material, carrying a lever, *a*, jointed at *b*. The lever carries a gun-metal or copper plate, *c*, bevelled so that it may wedge its way beneath the contact springs, *d d'*. If the main wire connects at *b*, and the branch at *d* or *d'*, or both together, the arrangement forms a single-break switch. In this way the current would flow through the joint *b*, which is not advisable. But if the main be connected to *d*, and the branch wire to *d'*, thus the arrangement becomes a double-break switch, and the current flows from contact *d* to *d'*, through the blade *c* only, thus encountering little or no resistance. Such switches should be furnished

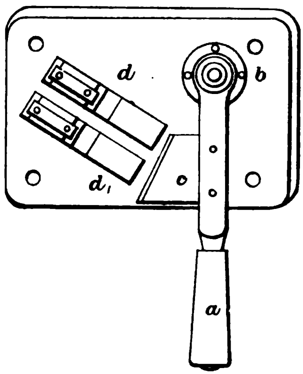


Fig. 41.—Single Hatchet Switch.

with covers, the wood being kept well away from the metal parts.

Two-way Heavy Branch Switch.—In Fig. 42 is depicted a switch of the same nature as that described above, but adapted for two circuits instead of one. The lever, *a*, with its plate, *c*, may be put in contact with the pair of plates, *d* or *d'*. In this way a *reserve* circuit, connected, say to *d'*, may be brought into working, upon the failure of that connected to *d*. The main connections will, in this case, be bifurcated, sending a branch to one of the contacts at *d*, and one of those at *d'*. The regular working circuit will be connected to the remaining contact of *d*, and the reserve circuit to that of *d'*. This arrangement is extremely useful for cabins and saloons, smoke-rooms and libraries, where reserve circuits are very often placed, to provide a means of continuing the lighting after the breakdown of the usual circuit. The same switch may be made useful for throwing the current off one circuit on to another, lighting an entirely different department of the accommodation.

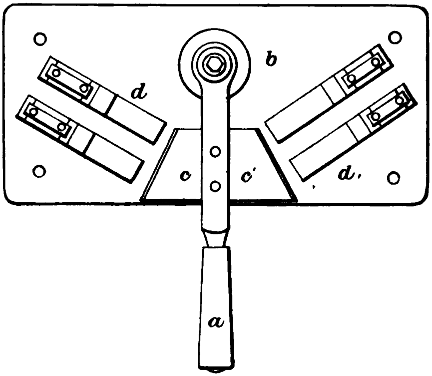


Fig. 42.—Double Hatchet Switch.

Small and Single Lamp Switches.—The smallest switches made are usually adapted to carry five ampères. We cannot here attempt a description of many of the numerous varieties, but will select one

or two as examples of the rest, so that the reader may possess an idea of the construction of such miniature circuit closers.

One of the most useful small switches is that known as the "tumler" variety, the interior arrangement of which is depicted in Fig. 43. It consists of a double contact, formed in the shape of two split contact blades, *a*, which can be depressed by the movement of the little ball lever, *b*, at the top. The

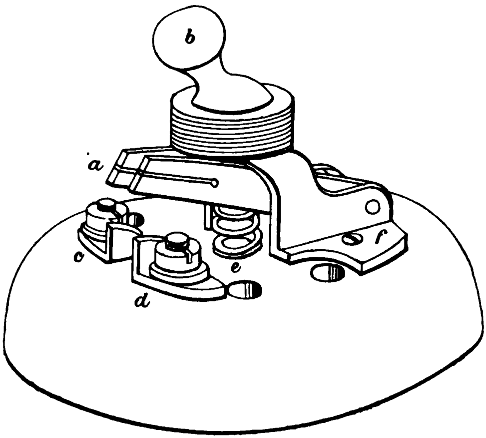


Fig. 43.—"Tumler" Switch.

twin contact closes the circuit by bringing the two blocks, *c* and *d*, upon the base into circuit through them. A strong spiral spring keeps the blades away from the contacts when the switch is open. When it is closed, the fulcrum of the lever is so placed that a jar will not cause it to fly open. But when the lever is moved slightly, the spiral spring, *e*, comes into play, and throws up the blades rapidly, opening the circuit with a snap. In this way the arc that

would be set up by the current, if the switch were opened slowly, is avoided. There being two contact

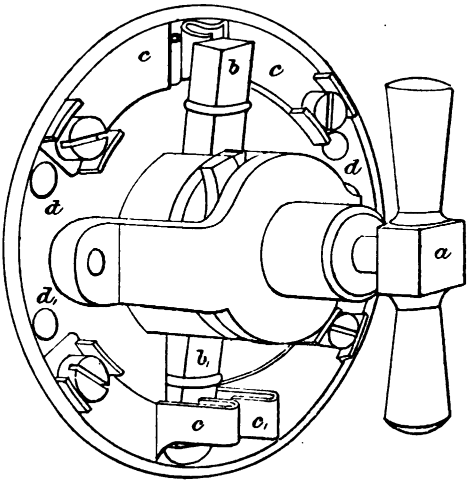


Fig. 44.—American Double-pole Switch—Interior.

points instead of one, the little spark that inevitably takes place upon breaking circuit is divided into two halves. In this way such a switch will last in use a long time before the contacts are so much burned as to be useless. The arrangement is hinged upon the brass bracket, *f*.

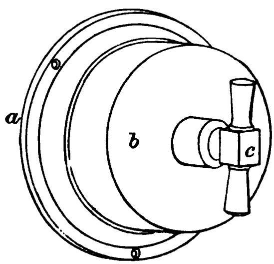


Fig. 45.—American Switch—Exterior View.

The American Switch, Figs. 44 and 45, is both double-pole and double-break. The lever *a* works *b* and *b′* by a cam action. The contact is made upon the spring clips *c* and *c′*. Conductors lead through *d* and *d′*.

An ingenious little switch for one lamp or a

number has been brought out by Mr. J. H. Holmes. Its arrangement is shown in Fig. 46, the cover and key being represented as removed to exhibit the interior. This consists of a narrow, oval-shaped central stem, *a*, having a spring with two free ends, *b*, upon either side of it. The contact is made when the lever *c*, forming part of *a*, is brought on to the fixed part or contact spring, *d*. When *a* is turned clockwise, the ends of the oval piece will separate the ends of the spring, *b*, which will bear heavily upon the ends of the oval. At this time the switch is "on." When the oval, *a*, is released slightly, it

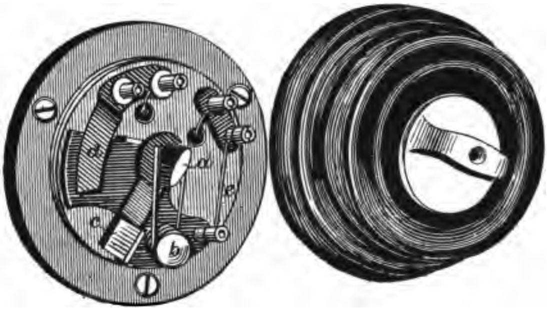


Fig. 46.—Holmes' Small Switch.

will fly round to the left by reason of the pressure of the springs upon the sides of *a*. The hand-key is so made that, after the release is given to *a*, it is free to fly away and break contact without being under control of the hand. In this way it is impossible to make an arc within the switch, which is very efficient when irresponsible persons handle the lighting arrangements. When the switch is fairly "on," it cannot fly back by accidental jarring, the contact-piece being held in a cam space below the contact-spring.

Rod Switch.—In many cases it is undesirable to place the switch controlling the lights in a department so that they may be interfered with by unauthorised persons. A device known as a rod switch is sometimes used for this purpose, consisting of an ordinary switch, the lever of which is furnished with two projections, one to right and left, so that the lever may be pushed to the "on" and "off" positions by means of a rod.

Key Switch.—But the most generally useful switch is that form in which the working parts are enclosed in a locked case, but providing a recess for a detachable key, which may be carried by an authorised person.

Inspection Switch.—Many portions of the interior of vessels are periodically inspected, at which time an officer may pass through them, but may only require the light during his passage. Entering at one end he turns on the light, but, on leaving at the other end is unable to extinguish it without returning. Such cases are met by the very simple arrangements of two switches represented in Fig. 47. On entering the department the first switch, *a*, is turned on, which allows the current to pass through the lamps, the circuit being made through the upper of the two mains, the negative wire of which is led to a switch at one end, whilst a similar switch at the other end is connected with the positive wire. Upon leaving the department, the second switch, *b*, is turned, thereby opening the circuit, and leaving the positive wire from the lamps ready connected with the second return wire, so that upon re-entering the place the lights may be turned on at either end as desired.

This arrangement of switches is now used exten-

sively in first-class staterooms having two berths, so that the lamp may be turned on or off by the occupant of either berth.

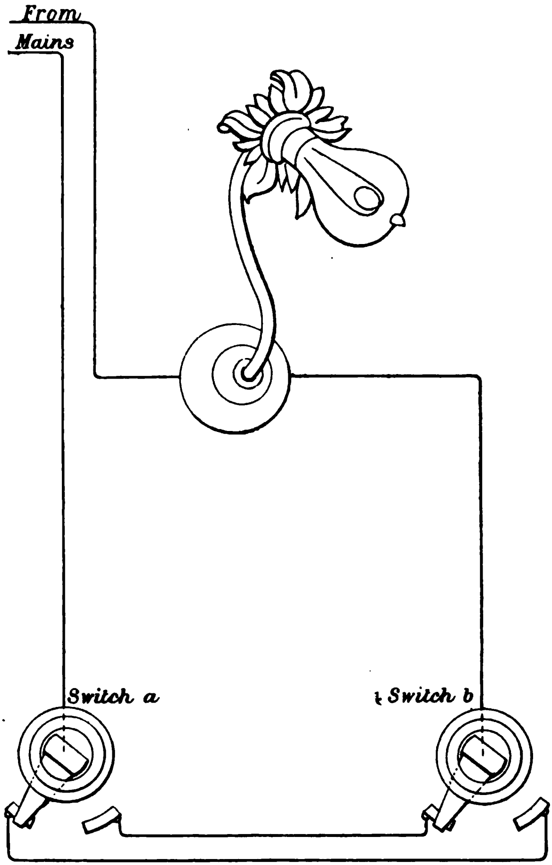


Fig. 47.—Occasional or Stateroom Switch, Double.

Fig. 48 represents a useful door contact, consisting of a bracket, *a*, carrying a spring and knob, *b*, *c* and *d*.

The door presses *c* and the light remains on while it rests in that position. This form is also used for bells.

The Fitting of Small Switches.—The fitting of small switches, forming as it does the detail work of the system, is apt to be left to the apprentices, and is, therefore, frequently performed in a very inefficient manner. Extra care should, however, be taken at such points, the more so as two wires are here employed, lead and return, and short circuits are very apt to be set up. It must not be supposed that the use of naked wire as a return, near to either lamps or switches, is to be recommended. On the contrary, insulated wire should be employed until the separation of the two wires is insured. When the two wires are brought together to the switch or lamp, they should be kept as far asunder as practicable.

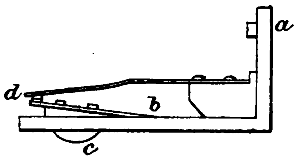


Fig. 48.—Door Contact for Lamp.

In making the connections to the series of switches cleanliness of contact is the first consideration, and tightness of contact is almost as important. Contacts may appear sufficiently secure that in a few weeks will work loose, owing to the jar set up by engines when "racing," and a great deal of trouble is caused thereby. The wire-ways through switch-bases should be plugged up watertight by means of putty or asphaltum compound.

The Incandescent Lamp.

It is well to be familiar with the nature and working of the incandescent lamp. In the want of proper

knowledge of the most approved way to treat the fine carbon filaments, the lighting will either be unsatisfactory or costly, by reason of breakages, or even expensive by reason of improper pressure in the wires. It is a great mistake to suppose that, because a low temperature and candle-power of the lamp appears to prolong its life, lighting in this way is economical. On the contrary, running lamps below their estimated candle-power is the most expensive form of lighting, even if it be shown that the lamp bill is greatly reduced thereby.

Economical Efficiency.—It is not economical to run lamps at a low pressure, because the light-giving power of the lamp varies approximately as the fifth power of the pressure at the lamp terminals. This is now well known. Those who run their lamps in a poorly-incandesced condition are not saving money; they are wasting it in coals for the furnace. But high pressure shortens the life of the lamp. There will, therefore, obviously be a balancing-point at which the cost of lamp-renewals and that of electricity will have a certain paying ratio to each other. As lamps are now sold it has been proved that the most economical efficiency is attained when the cost of lamp-renewals is about 15 per cent. of the cost of the entire lighting. If the cost of lamp-renewals is less than 15 per cent. of the whole, then the pressure of electricity in the mains is too low. If it is more than 15 per cent., the pressure is too high. If cheaper lamps were procurable, it is clear that the cost of renewing broken lamps would be much less than this. Hence it is clear that it does not pay to run lamps at so low a candle-power that they last beyond a certain number of hours. If a lamp burn 5,000 hours, a somewhat

rare "life," it is more than probable that it has cost its owner five times its value, and that it would probably have been cheaper to have run its life out in a fifth of the time, and purchase four new lamps.

Blackening of the Lamps.—The carbon vapour thrown off by the filament in its gradual destruction is deposited upon the interior of the bulb. Thus, after a few hundred hours, the glass is liable to assume a smoked appearance. Nothing tends more to reduce the light-giving power of the lamp than this partial opacity. When it has attained a certain density it is better to discard the lamp than to continue running it. At present this defect of the incandescent lamp cannot be overcome.

The Fragile Nature of the Lamp.—The light-giving filament is merely a fine thread or wire of hard graphite, a substance very similar to the carbon of gas retorts. It is made from various substances that can be carbonised to the graphite state. Cotton thread, treated with sulphuric acid, and afterwards carbonised in a retort, is extensively used. The filament forms merely a highly-resisting electrical conductor, which is easily made white hot by the passage of a small current. The higher its resistance the more economical it becomes. The average diameter of a series of common filaments was ascertained to be 0·150 of a millimètre. Its resistance varies when hot from 150 to 170 ohms, but when cold, it is much greater—in fact, nearly double. The filament, although possessing considerable resiliency, is easily broken, and a sudden jar may cause it to snap off at one of the platinum wires. The wires are of platinum, because that metal has a ratio of expansion and contraction nearly the same as glass, so that

the immission of air is thereby prevented. The bulbs, in the process of manufacture, are exhausted of air to a very high degree. Indeed, the vacuum in one of these bulbs is more perfect than any vacuum ever made by man before the advent of incandescent lamps. If air were to enter the globe the filament, when incandescent, would immediately combine with the oxygen, and would be consumed.

Current required by the Lamps.—The current varies according to the description of the lamp. An electrical horse-power consists of 746 units, called watts (volt-ampères). An average 16 candle-power lamp will take from 3·5 to 4 watts per candle-power, or from 56 to 64 watts. In this way from eleven to twelve of such lamps could be maintained by an electrical horse-power. An average 16 candle-power lamp, constructed to work upon a 100-volt circuit, will take a current of about 0·6 ampère. A similar lamp, capable of working upon a 50-volt circuit, being of much lower resistance, will require a current of one ampère or more. It is usual to allow the above currents for such lamps in getting out quantities for an installation.

The lamps in general use are 110 volt 64 watt, 100 volt 64 watt, 60 volt 60 watt, and 45 volt 6 watt lamps. A 100-volt lamp, if inserted across a 50-volt circuit, would not be lighted up. A 50-volt lamp, put upon a 100-volt circuit, would be quickly consumed. But if two 50-volt lamps be put *in series*, upon a 100-volt circuit, they will perform satisfactorily. If one of these should fail, however, the connection will be broken, and the other lamp will be extinguished. Hence it is clear that 50-volt lamps cannot be satisfactorily burned upon any but a 50-

volt circuit, nor can a 100-volt lamp be used upon a circuit conveying smaller or greater electro-motive force than that for which it was designed. It is well to remember that the light-giving power of the lamp is more than in proportion to the pressure expended upon it. Thus, the lamp at 90 volts might only be red-hot, but by an additional 10 volts pressure, it is fully incandesced. A slight fall or rise of pressure affects the light enormously. When a lamp is being served with too high a pressure, it acquires a bluish tint, and soon after breaks.

VOLTS AND CURRENT OF THE INCANDESCENT LAMPS.

2½	c.p.	from	about	5	volts &	1·75	ampères	to about	25	volts &	·4	ampères.
5	,,	,,	,,	10	,,	1·75	,,	,,	35	,,	·6	,,
8	,,	,,	,,	15	,,	1·9	,,	,,	55	,,	·6	,,
16	,,	,,	,,	13	,,	1·85	,,	,,	105	,,	·58	,,
25	,,	,,	,,	45	,,	2·0	,,	,,	105	,,	·9	,,
32	,,	,,	,,	55	,,	2·0	,,	,,	105	,,	1·05	,,
50	,,	,,	,,	80	,,	2·3	,,	,,	105	,,	1·6	,,
100	,,	,,	,,	80	,,	4·4	,,	,,	105	,,	3·3	,,
200	,,	,,	,,	80	,,	8·5	,,	,,	105	,,	6·5	,,
500	,,	,,	,,	80	,,	21·5	,,	,,	105	,,	16·5	,,
1000	,,	,,	,,	80	,,	43·5	,,	,,	105	,,	33·0	,,

Lamps of similar voltage, irrespective of their candle-powers, may be run together in one circuit. Lamps taking less than 0·9 ampère are estimated to require 4 watts per candle-power, and lamps taking more than ·9 ampères are estimated to require 3·5 watts per candle.

Ordinary Incandescent Lamps.—These consist of a pear-shaped bulb of clear glass, with either an Edison filament in the shape of a U, or a Swan filament forming a coil of a single complete turn. The latter is becoming the more common. The size of the bulb varies from 3 by 2 inches upwards. These are too well known to call for particular description.

Series Lamps.—Series running of lamps is rather rare. It is full of difficulties when several lamps are run together; but, in many cases, two or three lamps are put in series when there are a number of others, working in parallel with them. The certainty of extinguishment upon the breakage of one of the lamps is so troublesome, that, as a rule, not more than two lamps are run in series. The system is extremely economical. The "Ediswan" lamps for series work have heavy filaments, and carry a current of 6·8 ampères for all sizes, from 16 c.p. up to 50 c.p. Still thicker filaments are produced by the same makers, taking 10 ampères. The filament is short, and of low resistance.

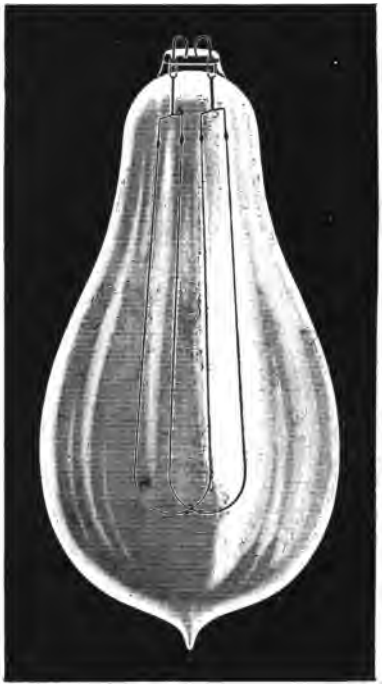


Fig. 49.—Twin Filament Side Lamp.

Ship's Side-Light Lamps.—The steaming lights are probably the most important in the ship. When ordinary oil lamps are used the lantern is generally furnished with a large red or green glass lens or bull's eye. This can be done when the light is at one point, but when incandescent lights are employed

the filament and light are usually elongated, and a lens would be useless. Hence it is the common practice to have the side-light lanterns with a plain glass front only. When incandescent lamps were first used for navigating purposes, they sometimes gave trouble by the breakage of the filament. Then the side light would go out and remain extinguished for some time perhaps without its attracting attention. This led to the employment of two of the lamps within the lantern connected in parallel to each other. This system worked very satisfactorily. But of late it has been improved upon by the introduction of the

Fig. 50.—Spiral Focus Lamp.

Twin-Filament Side-Lamp.—This type of lamp is depicted in Fig. 49. It consists of two distinct filaments connected to one pair of terminals in parallel. The connection to the platinum is so perfect that there is no danger of rupture, and the filaments themselves are strong enough to withstand rough usage. If one of the filaments should fail the other will continue the light. These lamps are hung in a lantern, having a plain glass (either red or green) front, and are a very great improvement upon the old oil lamp. They are usually of either 25 or 50 c.p., the latter being preferred by large steamers.*

Focus Side-Light.—The focus side-lamp is, how-

* In thick weather a powerful light is required, and it is a common practice to provide in the lantern two lamps, one or both of which may be used as required. In fine, dark weather a moderate light is preferred by officers on the bridge.

ever, so strongly in favour with some mariners, that objection is sometimes taken to lanterns not so provided. This is met by the focus incandescent lamp, depicted in Fig. 50. We have here an ordinary 25 or 50 c.p. lamp, the filament of which is coiled up into a volute. This concentrates the light to a very small area, and, as it is circular, it is undoubtedly superior to oil flames for distributing the light through the

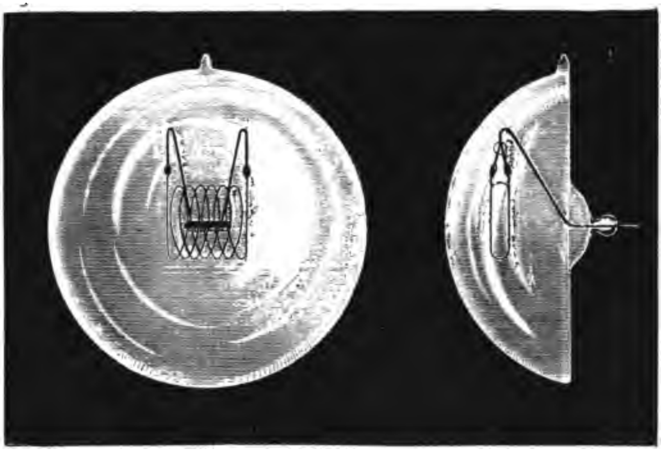


Fig. 51.—Focus Steaming Lamp.

lens. A still later form of the lamp, which can be procured in any required candle-power is exhibited in the two views given in Fig. 51. The first shows the front of the lamp, and the second the edge view. Doubtless this lamp could be made with two spirals in parallel, as in the case of the twin filament lamp described above, an advantage that would obviate the necessity of employing two lamps in one lantern. The advantage of the circular bulb lamp is that it can

be used in an ordinary oil lantern, without any preparation except that required to introduce the insulated leading wire. The return is sometimes made through the body of the lantern, when that is in metallic contact with the ship. If not, it is usual to bring a twin wire to the lantern, one of which forms the lead and the other the return. The connections of these lanterns are treated at great length further on.

Incandescent Lamp Holders.—It will readily be understood that, since the socket or holder of the electric lamp is required not only to support it mechanically, but to connect it electrically, the construction of such an arrangement calls for some ingenuity and good judgment. What is required aboard ship is a holder into which the lamp may be put with ease and certainty, and which will support it against all vibration, and at the same time afford a perfect electrical connection. This is by no means so simple a matter as may at first appear. A great many forms of holders have been tried during the ten years that incandescent lamps have been used in ship lighting. Many of them were good, but the majority failed chiefly in the provision of a really good electrical connection.

Figs. 52 and 53 represent the latest outcome of the endeavours to fully meet the requirements of ship lighting in the above respects. Here are depicted, in the former, a full-sized holder for a 16 c.p. lamp. It has a plain exterior appearance, with a gap for the bayonet joint of the lamp, cut from its edge. In the figure are exhibited the interior spring plunger electrical connections. This portion is fitted within the holder, which is represented in section, in Fig. 52. One only of the spring pistons is shown here. It

consists of a brass cylinder, *e*, attached to an insulating disk, *d*, projecting from which is a lug, having a set-screw for receiving the wire connection. Within the cylinder there is a spiral spring, *g*, of five turns. The piston is furnished with an enlarged flat head, so that it is prevented from falling out of the cylinder. The spring keeps the little plunger in the "out" position shown. The other cylinder and plunger are of the same construction. They are attached to an ebonite or steatite round base, *a*, which fits into the

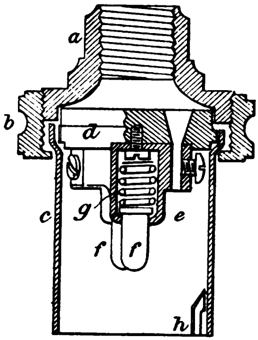


Fig. 52.—Ediswan Lamp Holder—Section.

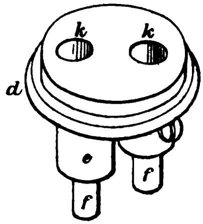


Fig. 53.—Holder—The Spring Contacts.

holder, the whole being secured by a screw gland, *b*, shown in section. When the lamp is put into the holder, its electrical connections touch the two spring plungers, which are pressed back by the lamp, when it is locked in the bayonet joint. The spring plungers keep up a tight contact, without in any way imposing strain upon the lamp itself. These holders are intended to receive the ordinary brass collar lamps, having one or two projecting joint-pins.

Holder for the Loop Lamps.—The brass collar adds somewhat to the expense of the lamp, and this

fact maintains in favour the plain bottom-loop lamps. These require a special holder, *a*, Fig. 54, having hooks, *b b*, to take the loops, and a spring to maintain the contact. This pattern is excellently adapted

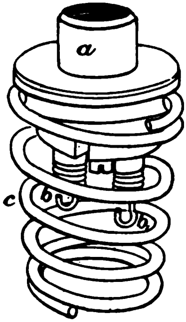


Fig. 54.—Loop Lamp Holder.

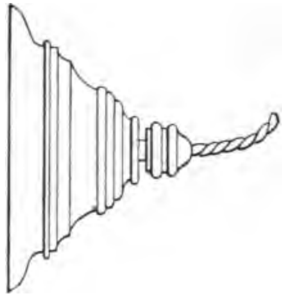


Fig. 55.—Wall Connection for Lamp.

for ships' use, being calculated to absorb the vibration, otherwise so destructive to slender glass work.

Plug or Wall Terminal for Portable Lamp.—The usual form of these is represented in Fig. 55. The most useful and safe form, however, for store-rooms and other ship purposes, is shown in Fig. 56, in which the plug, being large, carries a cut-out fuse, a very necessary precaution, because flexible leads are a source of much trouble, and by chafing into contact frequently cause a fire.

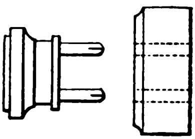


Fig. 56.—Portable Lamp Connector carrying Cut-out.

Plug for Cargo Lantern Cable.—This arrangement is similar to the previous figure, and consists of two contact holes, for split plugs or screw plugs, kept well apart, and a switch for turning off the current. The plug should always carry a cut-out adapted to the current taken by the lamps.

Portable Lead Socket for Collar Lamp Fixture.—It is very convenient to possess a means of fixing a portable lamp lead to any lamp socket near. This can be done by means of the adapter represented in Fig. 57, which may be quickly put on or taken off. A convenient connection for a collar lamp is shown in Fig. 58, which allows of the lamp being removed without disturbing the wall contact.

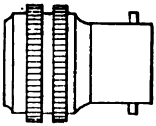


Fig. 57.—Portable Connector for Collar Lamp Fixture.

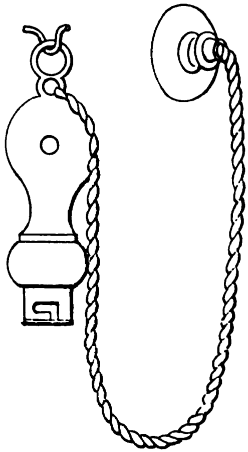


Fig. 58.—Wall Connection for receiving a Collar Lamp.

Single Lamp Cut-out.—It is usual to provide each isolated lamp with a small cut-out arrangement. When two or more lamps are attached to one electrolier, one central cut-out may be made to serve for all. The single cut-outs are generally in the form of ceiling plates, or wall plates. The base for the lamp and the cut-out are thus made in one part, which is a very convenient arrangement.

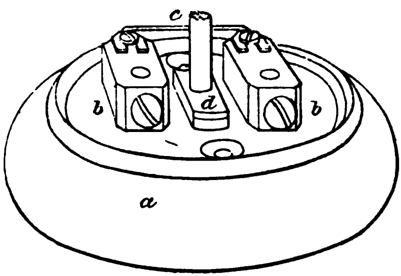


Fig. 59.—Branch or Lamp Cut-out.

In Fig. 59 is represented one of the Ediswan ceiling plates, carrying its own cut-out, of the latest form. It consists of a slate or porcelain base, pierced with holes for carrying the

wires from behind, and with screw-holes for attaching. The face of the base, *a*, carries two gun-metal blocks, *b b*, across which the fuse-wire, *c*, is fixed. A third block carries screws for the branch-wire and the lamp connection. Over all is placed a domed cover, fastened down with two thumb-nuts. This dome carries a screwed nozzle for the lamp connections.

Incandescent Lamp for Horizontal Position.—Many parts aboard ship can be more effectively illuminated by a horizontal lamp than by a vertical one. It is well known that the ordinary lamps are apt to have bent filaments if placed horizontally. The filaments are in fact too slender for the purpose. A

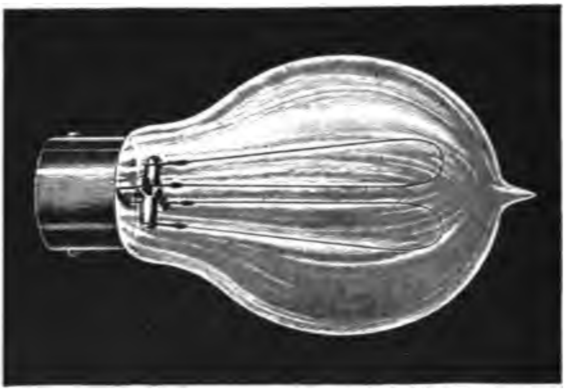


Fig. 60.—Lamp for Horizontal Position.

thicker filament answers the purpose, but it must be inordinately long to present sufficient resistance for high voltage circuits. The difficulty is well met in the construction of a lamp for horizontal running, lately brought out by Edison and Swan. This consists of two thick filaments *connected in series* within

the lamp. Thus the current flows first through one filament, and then through the other, forming virtually a long filament connected to supports in the middle. The two filaments are, however, separate and separately mounted.

Binnacle or Compass Lamps.—These are now extensively used in the best class of steamers, where they have entirely superseded the old oil lamp. When electric lamps were first tried for compass lighting, it was found that the current had an appreciable effect upon the needle of the instrument. A perfectly parallel, or preferably, a twisted arrangement of the conductors conveying the current to the lamp, served to modify the effect somewhat, but it was some time before it was discovered that the inductive effect remaining was due to the current in the filament of the lamp itself.

The usual arrangement of lamp is depicted in Fig. 61. It is not perfect, and has an appreciable effect upon the needle. It is, however, used extensively for bridge compasses, but not for the wheelhouse instrument. It consists of a metallic box *a*, containing the lamp *b*, showing through a glass *c*, the conductors being brought up through a tube, *d*. The best position yet attained is shown in Fig. 62, in which the lamp is placed on the axis of the compass needle, that is, vertically above it. The connecting wires, twisted together, are brought down from an overhead branch as represented. This method is used now for the wheel-house compasses of various large vessels.

Switch and Socket combined.—These are not so common as formerly. They consist of a small switch, moved by a projecting piece, after the manner of a

gas-tap. The whole is fitted within the confined space of the socket. For this reason, doubtless, the switch-holders are disliked by electricians, because they are too small to be made as thoroughly and as perfectly as can be done in a larger area, separate from the lamp itself. It is also more convenient to switch lamps off at some point in a room not occupied by the lamp. Holder switches are, however, very

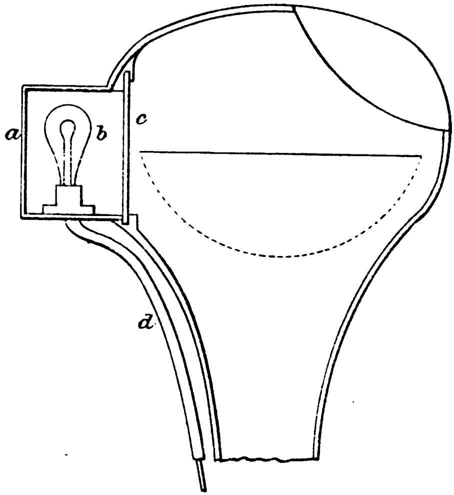


Fig. 61.—Bridge Compass Light.

useful for single lamps in some cases, and also for portable lamps.

500 *and* 1,000 *Candle-Power Cargo Lamps.*—In Fig. 63, p. 222, is depicted one of the high candle-power lamps now coming into use for loading and unloading purposes. The filaments are all arranged in parallel. The advantage of this arrangement is that if one filament breaks the others are not affected. The lamp may thus last for an indefinite time. The fila-

ments are arranged in a circle. The platinum con-

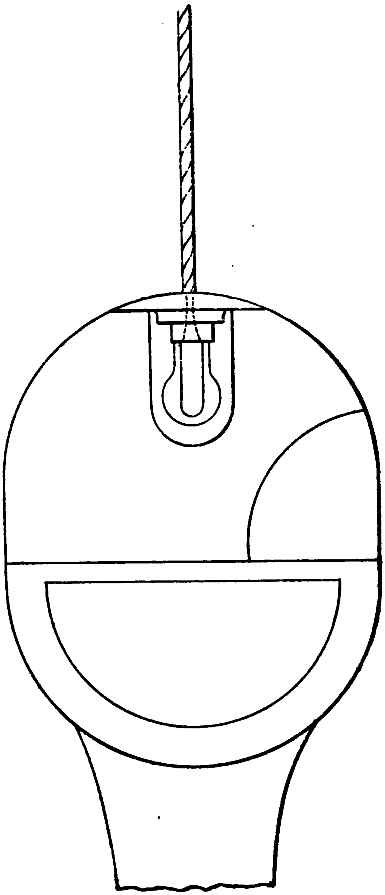


Fig. 62.—Steering Compass Light.

nections running through the glass are subdivided to get rid of the heat given off, and to give a more

perfect ratio of expansion between glass and platinum. The loops outside are engaged by lugs, to which the conducting wires are soldered. But sol-

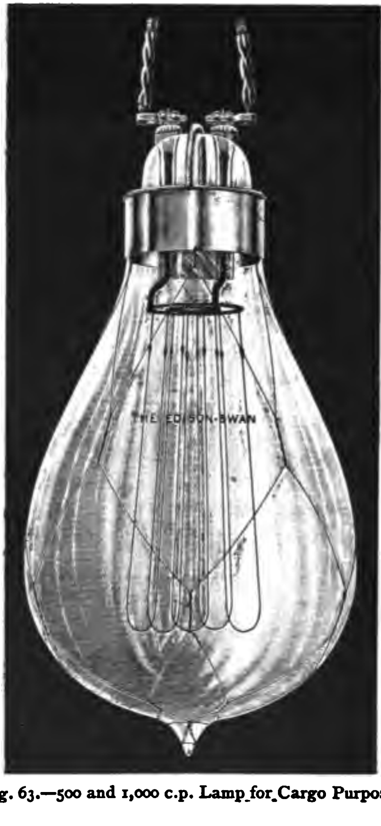


Fig. 63.—500 and 1,000 c.p. Lamp for Cargo Purposes.

dering alone must not be depended upon to support the lamp, because the heat set up may soften the solder.

It is thus better to pass the cable through the lug,

and solder in addition. Considerable heat is given off by the necks of such lamps, and brass collars attached by plaster in the usual way are not admissible. The loose collar shown in the figure supports the wire netting, which serves to catch the glass in the event of breakage.

Cargo Lantern.—Fig. 64 represents the kind of reflector found most generally useful for cargo lanterns. It is made usually in white-enamelled iron, but in many cases is merely painted within. There

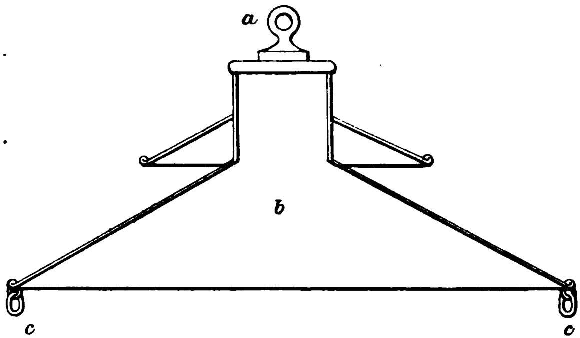


Fig. 64.—Cargo Lantern Reflector.

should be a means of egress for the heated air arising from the lamp or lamps, so as to assist in keeping the arrangement cool. At the top there is a ring for the suspension, and at either side rings for guy-ropes.

These lanterns are sometimes furnished with a group of 16 candle-power lamps, instead of a single lamp of high candle-power. The group is much more troublesome to wire. The lamps are all in parallel. A single 200 or 500 candle-power lamp is much better adapted to the work, but may be shown

to be more expensive in respect of renewal than a group of smaller and cheaper lamps. The same kind of cargo reflector as the above is used for the amidships overhead light now employed, in accordance with the rules of the Suez Canal Company, in passing through the canal by night.

Upper-Deck Reflector.—For the illumination of upper decks nothing is so effective as a large overhead incandescent lamp under a suitable reflector. The latter should be so curved as to diffuse the light

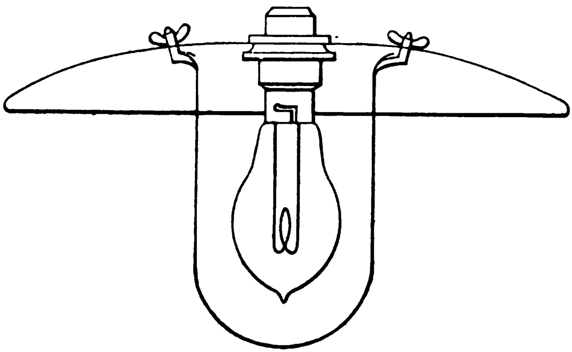


Fig. 65.—Deck Lantern.

over a large area. This kind of arrangement is clearly depicted in Fig. 65, wherein is shown the reflector fitted to the upper part of the lamp holder, where it is retained by a screw flange. The lamp itself is surrounded by an envelope of nearly U shape, of thin glass, made wide enough to be quite clear of the heat sent out by the lamp. The brim of this outer glass fits into three or more clips within the reflector, and is held by screws there as represented. A light lantern of this kind may be suspended by the cable supplying the current, a special

attachment being arranged to relieve the extremities of the weight. In order to prevent too great swaying, a guy-rope or cord should be attached to the edge of the reflector.

Bow-Spring Side-Contact Holder.—This holder is used for 16 candle-power lamps. The arrangement is shown in Fig. 66.

Adapter.—It is very convenient to possess a means for using loop lamps with the ordinary collar lamp holders. This can be done with the little adapter

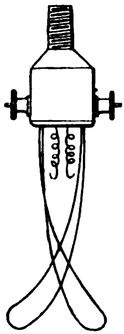


Fig. 66.—Adapter for Loop Lamp.

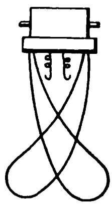


Fig. 67.—Connections for Collar Lamp Fixture.

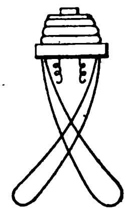


Fig. 68.—Acorn Holder with Cross Loops.

shown in Fig. 67. A somewhat similar adapter, intended for use with the Edison screw-holder, is depicted in Fig. 68.

Incandescent Lamps subject to vibration can be run with safety if fitted in the style of holder already described at page 215. Stateroom fittings are generally of plain, substantial pattern. Two forms of cabin brackets are shown in Figs. 69 and 70.

Ordinary Lamp Brackets.—We cannot in the space at our disposal attempt a description of the fittings used in cabins and saloons of ships. They differ

in no substantial way from house-fittings, unless it be that they are necessarily made more strongly, and, perhaps, with less pretence to ornamental effect.

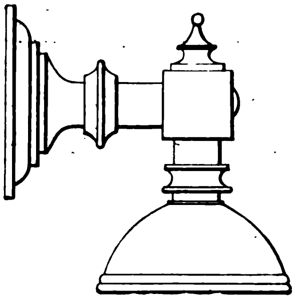


Fig. 69.—Cabin Bracket.

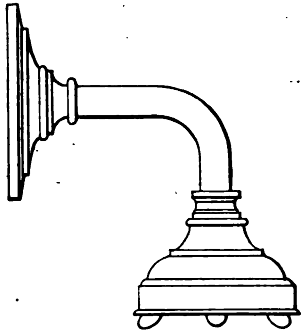


Fig. 70.—Cabin Bracket for Reflector or Shade.

But with regard to the special fittings lately developed entirely for ship purposes, it appears advis-

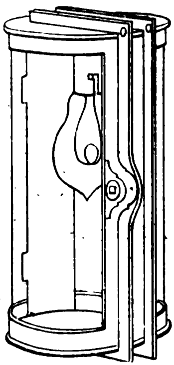


Fig. 71.—Two-way Bulkhead Fitting.

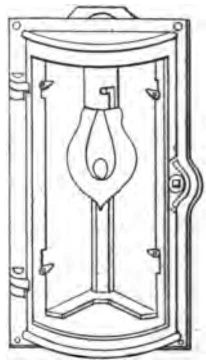


Fig. 72.—Three-way Bulkhead Fitting.

able to mention the more peculiar of these, and the purposes for which they have been specially designed.

Bulkhead Fitting for Incandescent Lamp.—Bulkhead lamps are a class apart. Fig. 71 represents a bulk-

head fitting casting light upon either side of the division. One of the glasses is clear; the other obscured. The fitting is furnished with a door capable of being locked with a key. Fig. 72 shows the same kind of fitting, but adapted for casting the light in three directions. The front glass is clear, the other two obscured. To accommodate these fittings, spaces are left in the bulkhead, and the fitting is attached with screws.

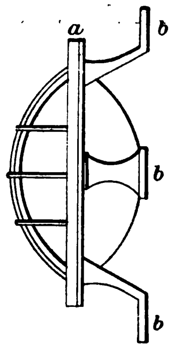


Fig. 73.—Bulkhead Oyster Fitting, guarded.

Oyster Fitting.—There are cases, however, when the bulkheads are intended to be water-tight, and cannot be pierced. These are met by a very compact form of lantern, called the oyster fitting, which is shown in Fig. 73. The glass is covered by a guard of wires in positions, such as stoke-holes and engine-rooms, when the lamps are liable to damage. But the oyster fitting, without the guard, is much used for cabins. The door, carrying the glass, is made to swing upon a hinge. The oyster fitting is also used for a two-way lamp, as shown in Fig. 74.

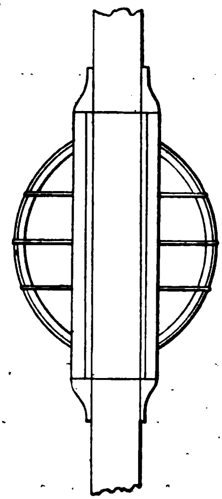


Fig. 74.—Double Bulk-head Oyster Fitting.

Roof-lamps.—These are made in two leading forms. Fig. 75 represents the usual roof pendant, which may or may not be surrounded by a guard, for use in stoke-holes. For the latter purpose it is made so that it may be easily removed from its plate, *a*, during coaling or when liable to injury. A

white reflector, *b*, furnished above, serves to diffuse the light. When the lamp is removed for this purpose a metallic cap, shown in Fig. 76, is used to cover the exposed terminals.

Engine-room Hand-lamp.—Engine-room lamps, capable of being carried about over a certain area,

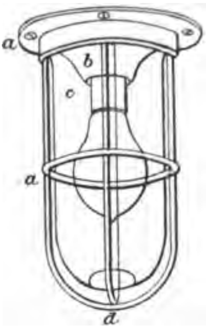


Fig 75.—Stokehole, Hold or Steerage Lamp.

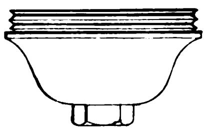


Fig. 76.—Cap for Exposed Lamp Terminal.

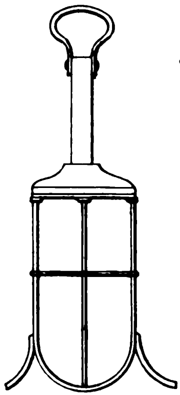


Fig. 77.—Portable Lantern.

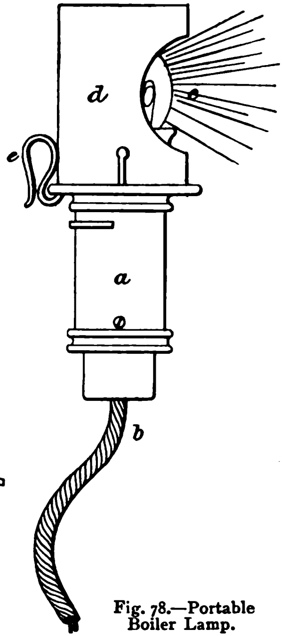


Fig. 78.—Portable Boiler Lamp.

are much used. Fig. 77 represents a useful form, well guarded. A long, flexible leading-cable is attached to the lamp, conveying the current from an adjacent wall stud. A smaller portable lamp, Fig. 78, is adapted for hooking to any convenient holder, and is frequently used in the interior of boilers. It consists of a holder, *a*, through which the wire, *b*,

leads. The upper casing has a reflector back, and contains the incandescent lamp, *c*. This form is generally of miniature dimensions.

Lamp Clusters.—Clusters of from three to twenty

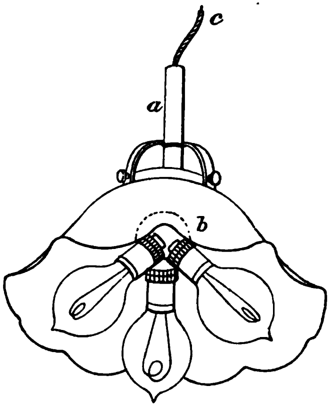


Fig. 79.—Three Lamp Cluster and Shade.

lamps are frequently used, the larger number especially for cargo purposes. The wiring of such work demands particular care. Referring to Fig. 79, a tube, *a*, ends in a brass globe, *b*, and carrying the two feeders, *c*. Particular care is necessary in making the branches within *b*, so that there shall be no chance of short-circuit; such clusters are troublesome aboard ship.

CHAPTER VIII.

CONDUCTIVITY AND INSULATION TESTING.

THE source of electricity used for taking the tests of conductivity and insulation is very often much too weak. This is especially true of the insulation testing as usually conducted. It was formerly considered sufficient to test the insulation resistance by means of the current from a pair of Leclanchè cells. Circuits that showed a high insulation resistance under these conditions would frequently break down when the electric-lighting pressure of 100 volts was turned on to them. The reason is not by any means obscure. Insulation-testing should be conducted by the aid of a current of at least as high a potential as the working current. Faults that will become apparent under these conditions would pass the weaker tests easily.

Hitherto the tests have been generally made with a Wheatstone's bridge and a voltaic current, but an improvement has recently been made in testing sets by Mr. Evershed, who has brought out a small portable magneto-electric machine, capable of giving a pressure of over 100 volts when turned by hand at a moderate speed. This is the source of electricity. It is fitted into a small portable case. The resistance-measuring instrument consists of an Evershed ohmmeter of simple construction. This instrument is

also portable, and permits of the insulation-resistance of a circuit being read off at once upon the dial. Hence, by the aid of this set it will be an easy matter for an untrained person to test the insulation. This, in itself, is of considerable advantage, which will no doubt be appreciated by those who have worked for years with the Wheatstone bridge. The ordinary wireman may be entrusted to take tests, and furnish reports of them to his chief before the circuits are covered in, so that weak points may be detected. The same set may be used for the conductivity tests, but these may, as hitherto, be conducted very well by means of a cell or two of the Leclanchè type, and a simple galvanometer.

The Evershed instrument is used as follows:—Place the ohm-meter in a fairly level position, not less than 18 inches from the generator, and see that the index comes to rest at some point on the scale, near the "I N F," so that the effect of any want of balance in the needles may be eliminated. Connect the + terminal of generator to + of ohm-meter, and the – terminal of generator to – of ohm-meter.

Before connecting on to the mains to be tested, turn the generator handle a few turns clock-wise. The index should move towards "I N F;" if it moves towards "O," the connections between the ohm-meter and generator are wrong, and must be reversed before proceeding with the tests.

Connect the mains or main and earth, the insulation of which is to be tested, to the *line* and *earth* terminals of the ohm-meter. Turn the handle of the generator about 70 turns per minute, and note the reading of the index. With the switch on the stud marked

$$\text{A—Resistance in Megohm} = \frac{\text{Reading of Index}}{10}.$$

With the switch on B—Resistance in Ohms=Reading of Index × 10,000.

Insulation Resistance Rules.—The five insurance offices insist upon a high insulation resistance of all electric light wiring. They each have their own rule, but it may be useful to show the requirements of ordinary work, as specified by various authorities.

General Rule for Ship Lighting Circuits.—Divide 10,000,000 by the number of lights; the result should be the minimum insulation resistance.

Phœnix Fire Office Rule.—For installations working at 200 volts or under, divide 12·5 megohms by the number of lights. The result should be the minimum insulation resistance. Double this if the current is alternating.

London Electric Supply Corporation Rule.—

Up to	25	lamps,	2	meghoms
,,	50	,,	1·25	,,
,,	100	,,	0·75	,,
,,	153	,,	0·5	,,

Institute of Electrical Engineers.—Multiply the volts by 7,900 and divide by the number of lamps. The result should be the insulation resistance in ohms.

Importance of Testing at the Working Voltage.—The following figures, due to Mr. Uppenborn, exhibit the importance of testing the insulation at a voltage at least as high as the working pressure. They also show the difference of the resistance at various pressures.

I.		II.	
Volts.	Meghoms.	Volts.	Meghoms.
5	68	5	281
10	53	10	188
13·6	45	16.9	184
27·2	24	27·2	121

Making the Insulation Tests.—These tests should be made not only while the ship is being wired, but at periodic intervals afterwards. This is of far greater importance aboard ship than ashore. It may be pointed out that from the nature of ship wiring and the unfavourable conditions under which the insulation has to be maintained, the latter is *continually deteriorating*. Instances are common in which the extensive wiring of large vessels has so far broken down that a complete re-wiring of the ship had become imperative within a few years of installation. This is not due simply to defective work at the outset. Its occurrence is rather to be attributed to the atmosphere aboard ship; to changes of temperature below deck; to "sweating" of the bulkheads and fittings, and to the effects of sea mists and water above decks, or in exposed positions. If the reader should care to question any attendant of a sea-going electrical installation, he will probably be informed that the condition of the circuits is never constant. There is occasionally great loss of power, heated leads occur, cut-outs "go," lamps are destroyed, and there is an ever-increasing difficulty to maintain the insulation perfect. These occurrences are the more marked when the wiring has been done in a second-class manner, or when a cheap kind of insulation has been selected. If these observations apply forcibly to

double wiring, which is somewhat uncommon, they apply with increased emphasis to the single-wire system, in which the insulation resistance is simply halved.

Insulation tests are taken in two ways. The most common is to take each circuit separately. But what does and does not constitute a *circuit* in a single-wired ship is a question few can answer. It can only be said that since one main breaks into numerous forks or branches, the mains must be regarded as the commencement of the circuits, while the ship's body, or earth, constitutes the termination. According to the other method, the whole of the circuits are grouped together, and the resistance over all ascertained. This latter method is advocated by the fire insurance offices, but it is doubtful whether it is so useful to the engineer in detecting the weak points in the wiring.

In taking a test of a single circuit all lamps are switched off, so that the termini of all the branches shall be insulated. The main is then disconnected from the chief switch-board. The testing electromotive force is then applied to the main by means of a magneto machine, giving a pressure preferably in excess of the working pressure. It must be clearly understood that the object of the test is to ascertain the condition of the insulation. The insulation is that which separates or isolates the conductor electrically from the ship's shell or the earth. If the insulating covering of the wires be weak, the test will exhibit a low insulation resistance. Since the test is intended to ascertain the possibility of establishing a circuit between the main wire, its branches, and the shell of the ship, it is clear that while the

positive pole of the source of electricity is to be applied to the main, the negative pole of the source is to be applied or connected to the ship's shell.

Insulation resistance tests should be taken not only before the dynamo is turned on, but after it has been working upon the circuits for several hours. This preliminary working frequently brings out weaknesses, and a test showing high resistance at the outset may read very differently after the lamps have been incandesced for some time. The figures obtained should at least attain to those specified in the rules already cited.

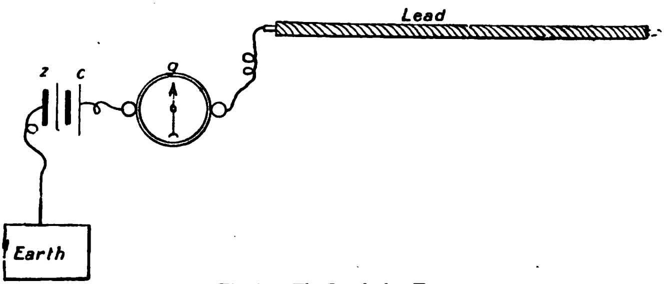
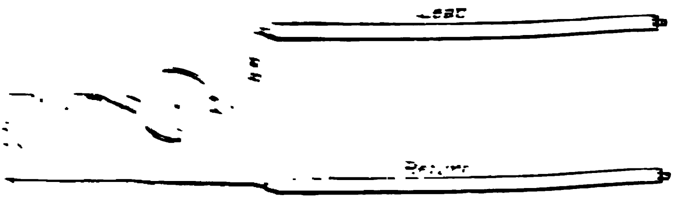


Fig. 80.—The Insulation Test.

Simple Insulation Test.—Many installations of the electric light aboard ship are allowed to commence work without any figure relating to the insulation resistance having been determined upon. In such cases the simple test of merely employing a source of electricity and a common galvanometer is generally all that is instituted. One pole of the battery is connected to the ship; the other is connected through the galvanometer to the main to be tested. If any deflection occurs in the galvanometer it indicates a leak or short-circuit. If it is a decided, strong deflection

[illegible] is probably a metallic short-circuit [illegible]. [illegible] it may indicate [illegible] or other poorly con[illegible]. [illegible] arrangement is shown in [illegible].

[illegible] by working with [illegible] the main. The [illegible] is connected to its "ship [illegible]." [illegible] leads off through a [illegible] the main wire. [illegible] be switched off this [illegible]. There should be a switch between [illegible] the galvanometer. Upon turning



[illegible] of the galvanometer will [illegible] a bad leak or a short-[illegible] there exist a slight leakage. [illegible] such a test the voltmeter should be [illegible] the dynamo, so as to certify that the [illegible] full voltage. This test, as applied [illegible] wire system, is shown in Fig. 81.

[illegible].—This is the simplest, and at the same time the most essential test. To conduct it, all the lamps are to be switched off. Then, if the main should send out several branches, the longest of these should be taken first, and its extreme end [illegible] "ship return." If there is a lamp at

the extremity, it will suffice to merely switch that lamp on. If the wiring be on the double principle, the last lamp across the leads may be turned on. The main is disconnected from the dynamo. A small source of electricity (such as a Leclanchè cell or two) has its negative pole put in connection with "ship return," and its remaining terminal connected to a sensitive galvanometer, this in turn being connected to the main. If there is a break in the wire at any point, the galvanometer will not deflect. If it deflect but feebly, the continuity is probably imperfect owing to a bad contact somewhere, or an unclean joint. The next shorter branch is examined in turn, and so on with all the mains and their branches. These tests, if satisfactory, merely prove that there exists a metallic path through which the current flows.

Tests for Crosses or Short-Circuits.—This test is of great importance, and it should be conducted with persistence until the wireman is satisfied that there does not exist any short-circuit between any wire and any other wire throughout the installation. The source of electricity used is frequently very weak. This is a great mistake. A feeble electro-motive force does not readily detect small faults. The pressure should be at least as great as the working pressure. In the absence of a magneto-machine, giving a pressure of 100 volts, the dynamo itself may be utilised as a source of pressure. Insulate the whole of the leads and branches by switching off all lamps. Let the negative terminal of the dynamo be kept connected to ship return. Connect the galvanometer to ship and to the first lead. Group all the remaining roots of mains together, and connect the positive pole of the dynamo to the group. Provided the

dynamo is excited, which may be ascertained by the aid of the voltmeter, any cross connection will at once be shown upon closing the circuit. The main is now to be insulated and grouped with the others, a fresh one being taken and tested in the same way, until every one of the mains has been compared against all the others. If no deflection of the galvanometer be obtained the inference is that the wiring is free from short-circuits at the working pressure. If a deflection be obtained the mains are to be disconnected from the group one by one until the needle falls back, exhibiting between which main and the

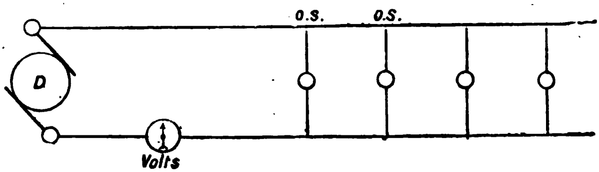


Fig. 82.—Voltmeter Test for Leakage between Leads.

one under test the cross occurs. This arrangement is represented in Fig. 82.

The Lamp Test for Earth Leakage.—In the case of the ordinary wiring, laid carefully in casings, the most troublesome leakages that occur are leaks to earth. In single wiring it is only necessary that there should be a leak to earth to set up a loss of current; but in the case of double wiring, a fault admitting of a leak to earth does not necessarily imply a leak. Provided the dynamo be well insulated from the ship, *one* fault of this kind cannot *per se* set up a leak. It requires the assistance of another leak upon a return wire to insure a loss of current. It will thus be clear that the system of single wiring is

at least open to the objection that leaks are much more liable to occur than in the case of the double system.

The most useful detector of earth leaks on the double system is the earth lamp, a device that may be employed to inform the attendant of the most incipient fault, as well as the detection of considerable leaks. The use of earth lamps is a device by no means new, but it is so seldom employed in

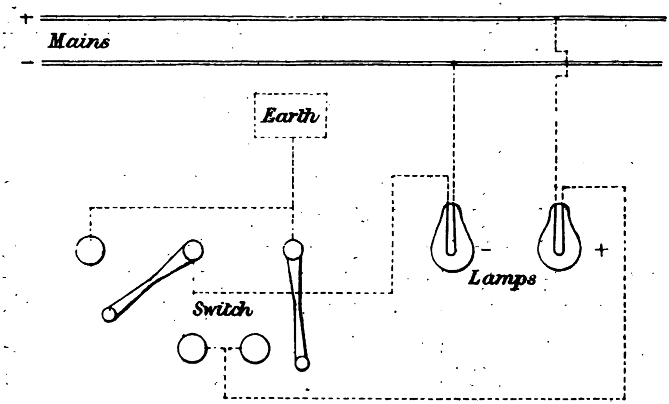


Fig. 83.—Earth Lamp Test for Leakage.

an efficient manner that a minute description of the best arrangement of them for ship work may prove useful to the reader. Two lamps of the voltage of the circuit are fixed in a convenient position close together. A wire is taken from lamp +, Fig. 83, to the leading main to be tested, and another wire is taken from — to the return main. The remaining wires from the two lamps are taken to a switch of the construction shown, which is designed to put the lamps in series with each other, and to put their

junction wire to earth, and also to put either lamp to earth as desired.

If the right lever of the switch be moved to the left the lamps will be in series. They will burn almost equally bright, but will obviously be only in a half incandesced condition. If, now, the left lever be moved to the right, the connecting wire between the lamps will be put to earth. If there should exist a leak, the relative candle-powers of the lamps will be disturbed, and one of them will burn more brightly than the other. This would occur if a leak existed from the leading wire to earth, because lamp and the leading wire will be in parallel. Hence a greater current will pass through one than the other, and they will burn with different effects, dependent upon the magnitude of the leak. If — should brighten up upon shifting the right-hand lever, it will indicate that there is a leak upon the return wire. The extent of the leak will, to a certain degree, be indicated by the relative brightness of the lamps. Although the earth lamp test is useful in manifesting the existence of a leak, it is of no assistance, as described, in locating its position.

Location of the Leak.—A single earth lamp is, however, very generally used to discover the exact branch in which the leak occurs. A lamp furnished with a flexible pair of conductors is taken. One of these is to make connection to the ship itself, the other to the main or branch to be tested. Beginning at the main switch-board, a connection is made to each main until the faulty one is indicated by the incandescence of the lamp. This main is now to be followed up, and a connection made at the first switch, which is opened for the purpose, breaking the circuit, or cut-out upon it.

If the lamp now fail to burn it will be clear that the leak exists between the switch-board and the first cut-out. Each succeeding cut-out or switch is tested in the same way until the lamp fails to burn when connected to the disconnected end of the wire suspected. The first failure of the lamp to light up indicates that the leak is upon the section just passed.

Leaks of less than half an Ampère.—These cannot so readily be detected by a lamp, and a galvanometer will in such cases be found more useful. It is employed in the same way as the lamp, a deflection of the needle taking the place of the incandescence of the latter.

Permanent Earth Lamps.—When the double-wire system is used, it is a common practice to keep one lamp connected to the ship, and also with its other pole connected to every leading main upon the switch-board. This lamp is kept well in view, and the occurrence of any leak is at once observed by its incandescence. A similar lamp is connected to the return mains. When a leak occurs, each main connection is cast off singly until the lamp ceases to burn, thus indicating the particular main in which the leak exists.

Exact Location of the Leak.—The earth lamp is of no assistance beyond showing in which branch the leak occurs, and between which two switches it lies. To locate it more exactly, it may be necessary to carefully trace the wire-casing, placing the hand upon it to ascertain whether there is a hot place therein. Damp or wet may generally be detected by the eye from outside evidence.

When a portion of casing is suspected, it should

be removed, and the wire within examined. The most troublesome faults of the double-wire system are those leaks or short-circuits that occur from lead to return in the same casing. These are almost invariably due to damp. But sometimes an accident may occur, as the driving of a nail into the casing, causing a very bad short-circuit. It will readily be seen, in view of the detection of leaks, how necessary it is to place casings in accessible positions.

Voltmeter Test for Earth Leakage.—When the resistance of the voltmeter is known, a leakage to earth

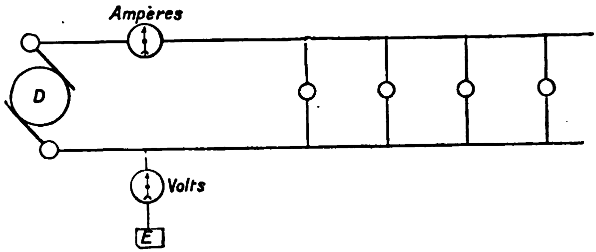


Fig. 84.—Voltmeter Test for Leakage.

may be detected by calculation. The ampèremeter is put in the circuit as usual. The lamps are switched on. The voltmeter is connected across from the return wire to the ship or earth. Then by Ohm's law, noting the volts shown by the latter:

$$\frac{E}{R} = C.$$

The current C, shown by the ampèremeter, and that, c, due to leakage, should be noted; then:

$$\frac{C}{c} = K,$$

K being a constant representing the insulation resistance. The arrangement is shown in Fig. 84.

Single-Wiring System Tests.—Tests for leakage in the single-wiring system are few in number and generally unsatisfactory. If the farther ends of the branches be insulated and all lamps turned off, no current should be indicated by the ampèremeter when the dynamo is running, if there is no leakage. A more delicate test is obtained by switching off the dynamo, and putting a magneto-machine giving 100 volts in its place, using a delicate galvanometer in place of the ampèremeter. A very slight leakage can be detected in this way. This is really an insulation test application to one wire. So long as the insulation test of the single-wiring system is satisfactory, other tests may generally be dispensed with, except it be an occasional test of the conductor resistance. The latter test is carried out by the aid of a Wheatstone's bridge and set of resistances, after the manner fully set forth in the author's work on *Electric Light Fitting*, p. 78.

Comparison of Fall of Potential Resistance Test.—The following simple method of taking a resistance measurement of a circuit has been found very useful by ship's electricians, as it affords a means of periodically testing the integrity of the circuit and discovering faults in the connections or contacts at switches and cut-outs. Procure a wire measuring one-hundredth of an ohm, and another wire of rather over one hundred ohms. Connect them in series with a source of electricity giving a few ampères of current. Make ship contact with the remaining pole of the electric source. Make ship contact at the far end of the leading wire (all lamps being off). For the measure-

ment use a reflecting galvanometer. Connect the terminals of the galvanometer with the two extremities of the hundredth-ohm coil. Note the deflection. The comparison is got by making connection with the galvanometer to the two extremities of the circuit. Note the deflection in this case also. These deflections are strictly proportional to the fall of potential in the two cases, and the resistance in ohms of the circuit is at once ascertained.

In order to insure against uncertainty of reading, it is necessary to restrict the current flowing to the smallest that will be practicable to give a deflection upon the galvanometer. This is effected by means of the 100 ohm resistance, which, being in series with the source of electricity and the circuit, acts as an impedance or choking coil to that extent.

The above method may be made very useful in ascertaining, in a simple manner, the resistances of short lengths of cable, or of coils. It is especially useful in the work of testing dynamos for short-circuits, especially in respect of the armature coils, a method which is particularly described in the author's *Electric Light Fitting*, p. 74.

Test for the Working Resistance.—The resistance of a parallel system of electric lighting is strictly a divided resistance, of which the component parts are the leading wires, the lamps and the return part of the circuit. The resistance of such a system when cold is enormous, chiefly due to the carbons of the lamps. But when working, the resistance falls very considerably. The greater the number of lamps, the greater the number of paths there are for the passage of the current, and the smaller the resistance—the resistance is inversely as the number of lamps, nearly.

If the resistance of one lamp be known, the resistance in circuit (neglecting the leading wires) is easily ascertained by the rule

$$R = \frac{\text{Resistance of a single lamp, incandesced.}}{\text{Number of lamps in parallel circuit.}}$$

By Ohm's law the resistance may be ascertained by the aid of the volt and ampèremeter, while the circuit is working. Connect the voltmeter near to the dynamo, in parallel—that is, across—from lead to

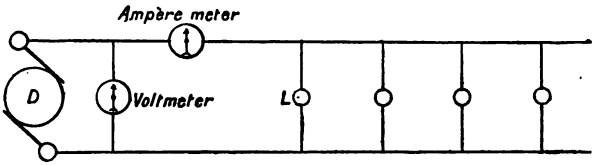


Fig. 85.—Working Resistance Test.

return. Connect the ampèremeter in circuit upon the leading wire; then, having noted the readings of both instruments, and calling current C, volts E, and resistance R—

$$\frac{E}{C} = R.$$

The connections are outlined in Fig. 85.

But it is not always that these tests are satisfactory, owing to fluctuations in the current and want of care in making the test. It is advisable to repeat the test at intervals and from this deduce an average. At best this test is only, practically, an interesting one; since it is plain, from the nature of the incandescent lamp, that its resistance cannot be two days alike—it is in fact a resistance that is constantly becoming greater until the lamp breaks.

The above facts render clear the reason for the seemingly strange behaviour of series-wound dynamos, in the early days of electric lighting, which, while they had power enough apparently to light up fifty lamps, were seemingly powerless to light five or even one. The current that would pass a small number of lamps was insufficient to excite the magnets of the machine.

CHAPTER IX.

ACCUMULATORS IN SHIP-LIGHTING.

THE storage of electricity is useful in two specific ways: 1st, it becomes valuable when the dynamo has to be stopped for any reason, as want of steam or by accident, and it enables the lighting of the few "all night" lamps to be maintained when it would be a comparatively costly process to maintain the dynamo in motion. These conditions are of frequent occurrence on board the smaller craft, and especially in the case of yachts. 2nd, the accumulator is almost indispensable as a regulator in cases where the dynamo is moved by the main engines of the vessel, or by an indifferent independent engine.

Accumulators are, contrary to general belief, singularly efficient on board ship. They give little or no trouble, and when well arranged are an unquestionable advantage. The cells, far from exhibiting any symptoms of faulty action by reason of the motion of the vessel, are undoubtedly kept more fully up to their work thereby. The electrolyte, which, when kept quite still, is apt to settle down into strata of different densities, is so maintained in motion at sea as to preserve an uniform specific gravity, a condition which not only leads to free working, but maintains the electro-motive force and internal resistance uniform.

Material of the Cells.—This is a question that has

been much debated. Accumulators are generally placed in glass boxes for land purposes. The main reason for this is that the transparent material permits of the free examination of the plates within, and their working condition generally. Those who have used accumulators will admit that the free examination of the interior is an almost essential condition of successful working, and for this reason glass cells are undoubtedly the best for general purposes, including ships' use, provided that care be taken to so place the cells that they will be protected from rough usage. It must not be supposed that an accumulator may be stowed away in any kind of dark out-of-the-way place. Whether the cells be of glass or of less breakable material, the place chosen must be clean, cool, well lighted, and dry. These conditions are essential, otherwise faults not due to the storage system will be continually laid to its charge.

The use of hard-rolled lead containing cells has been very strongly advocated, and no doubt this material comes next to glass in point of suitability. Ships' accumulators are, indeed, very generally put into lead cells, although wood as a containing vessel is both cheaper and lighter, and answers fairly well.

Inclination of the Liquid in the cell, when the ship is rolling, is generally met by fitting the vessels with covers. But except under exceptional conditions a battery with cells entirely open performs with greater satisfaction. The inclination seldom exceeds 35 degs., and this can easily be met by extra deep vessels, so much higher than the plates that the latter are not left even partially uncovered at the full inclination. But in the case of both lead and teak cells, covers are usually supplied by the makers, which renders spilling impossible. The chief reason

for examining accumulators through a transparent cell is to maintain a watch upon the condition of the plates, but more particularly to prevent the lodgment between the latter of loose plugs of the packing material of the plates. These tend to short-circuit the cell and otherwise weaken the working. Loose pellets may be observed at once within a glass cell, and may be dislodged by means of an ebonite stick. The same means may be used to ascertain whether there are any loose pellets between the plates of a lead or teak cell, when the eye cannot detect the obstruction. But in the latter case time is lost in testing every cell. To meet these conditions the *celluloid separator*, consisting of a perforated plate of that material, is coming into general use for purposes of insulating the plates, in case either of loose plugs or distortion by buckling and consequent contact. The separators are very useful for ships' accumulators, when the battery may be left unattended for long periods.

Nature of the Accumulator.—The secondary battery has been so often described that it will be unnecessary to dwell upon its construction and principle of action. The plates are lead plates, perforated more or less ingeniously, and packed with plugs of minium and litharge. The electrolyte is diluted sulphuric acid. The electro-motive force of the cell is a trifle over 2 volts.

Most Suitable Electrical Pressure.—In cases where accumulators are used, a pressure of some 55 volts appears to be the best. Since the accumulator cell may be taken to be capable of maintaining 2 volts only, 26 cells are required to form the battery required in this instance. 50-volt lamps are supposed to be employed, with a dynamo capable of giving

2·5 volts for every cell to be charged. Thus the dynamo must yield a pressure of 78 volts, and it must be *shunt-wound.* In estimating the number of cells required, it is usual to divide the voltage of the lamps by 2 and to add 2 cells to the total thus found. Where 100-volt lamps are used the voltage is to be divided by the same number, but three additional cells are required to make up for loss of potential in leading wires. A battery of 53 cells is rather cumbersome, and 100-volt lamps are seldom used in such cases for this reason. The usual battery consists of 26 cells intended to work 50-volt lamps.

Position of the Accumulators.—It is advisable to arrange for a separate apartment for the battery, above the water line, where daylight may enter, and where efficient ventilation may be arranged for. A strong wooden shelf, placed at a height convenient to render the connections of the cells accessible, is all that is required. The shelf must have a space between its back ledge and any ironwork of the ship, to permit of ventilation behind the cells. If light can be transmitted through the cells, in the case of glass boxes, it will prove of great advantage. The cells are usually insulated from the shelf beneath by oil insulators, in the form of small duplicate cups, now supplied with all accumulators. For purposes of steadying the cells from above, pitch-pine rails are useful, with hard rubber studs inserted where they bear against the cells. Shelving for this purpose should be built of hard wood, and thoroughly varnished.

The fittings for receiving the cells should provide for the tendency to displacement caused by both pitching and rolling of the vessel. If space is available, it is an advantage to provide a passage for the

attendant behind as well as in front of the cells. The whole battery must be kept clean, and its shelf and insulators maintained in a perfectly dry condition. The position of the accumulators should be well screened from any metallic work, as dynamo or engine, which might be injured by any possible acid spray given off in the process of charging. Between glass cells and glass insulator cups, slips of wood must be placed to prevent sliding of the glass surfaces upon each other. When the battery is to be arranged in two tiers, ample space must be left between them.

Before First Charging.—It is essential that on first charging the process should be continued for about 30 hours, without cessation. The dynamo must be tested for a long run for this purpose, so that no cause for interruption of charging may occur.

PARTICULARS OF K TYPE OF E.P.S. STORAGE CELLS.

Number of Plates.	Acid for each Cell.		Working Rate.		Approximate External Dimensions				Weight of Cell without Acid. *Approximate.*
	W'ght of Acid.	Part of carboy.	Charge Ampère.	Discharge Ampère.	L'nth	W'th	Hei't of Box.	Hei't over all.	
	lbs.				ins.	ins.	ins.	ins.	lbs.
7	25	·23	15 to 25	1 to 25	5½	11½	13½	16½	56
9	30	·27	18 " 33	1 " 33	6½	"	"	"	70
11	35	·32	22 " 42	1 " 42	7¾	"	"	"	86
13	39	·35	26 " 50	1 " 50	8½	"	"	"	101
15	44	·40	30 " 58	1 " 58	9⅝	"	"	"	117
17	50	·45	34 " 67	1 " 67	10¾	"	"	"	133
19	56	·50	38 " 75	1 " 75	12	"	14	17	154
21	62	·56	42 " 83	1 " 83	13	"	"	"	165
23	67	·60	46 " 91	1 " 91	14¼	"	"	"	181
25	73	·66	50 " 100	1 " 100	15¼	"	"	"	197
27	79	·71	54 " 108	1 " 108	16¼	"	"	"	212
29	85	·77	58 " 116	1 " 116	17¼	"	"	"	228
31	88	·79	62 " 125	1 " 125	18¼	"	"	"	242
33	90	·81	66 " 135	1 " 135	19	"	"	"	258

The above K cell is the latest improved form introduced. It is known as the High Discharge type. The normal maximum discharge rate is 8 ampères per peroxide or positive plate. For short periods this rate may be increased, but at some risk of shortening the life of the plates. The capacity of maximum discharge is about 28 to 36 ampère hours per positive plate. At half the rate mentioned as maximum above (or a discharge rate equal to that of the older "L" type cells), the capacity is about 32 to 42 ampère hours per positive plate. Discharge should be considered complete when the pressure falls to 1·85 volts per cell.

Size of Cell and Number of Lamps.—The number of cells for any number of 50-volt lamps will, as already mentioned, be 26. The size of the cell and the number of its plates, as specified above, will depend upon the time the current is required to flow from the accumulator and upon the number of lamps to be maintained. At full discharge the smallest size tabulated above will maintain 25 lamps, but it is better to work much under maximum discharge except in emergencies. The next size will take 33 lamps, the third 42, and so on, assuming that each lamp requires approximately one ampère of current. The smallest battery of the K type, 26 cells, occupies with spacing about 13 feet of shelving, having a depth of 12 inches, and the extreme height is only 16½ inches. This compact and powerful accumulator is admirably adapted for small steamers and yachts.

Connections of Dynamo and Accumulators.—Fig. 86 will serve to explain the best way in which to arrange the connections of the dynamo, current alarm bell, switches and accumulator with lamps. It will be seen

that the first and last regulating cells may either be kept in or cut out during either charging or discharging.

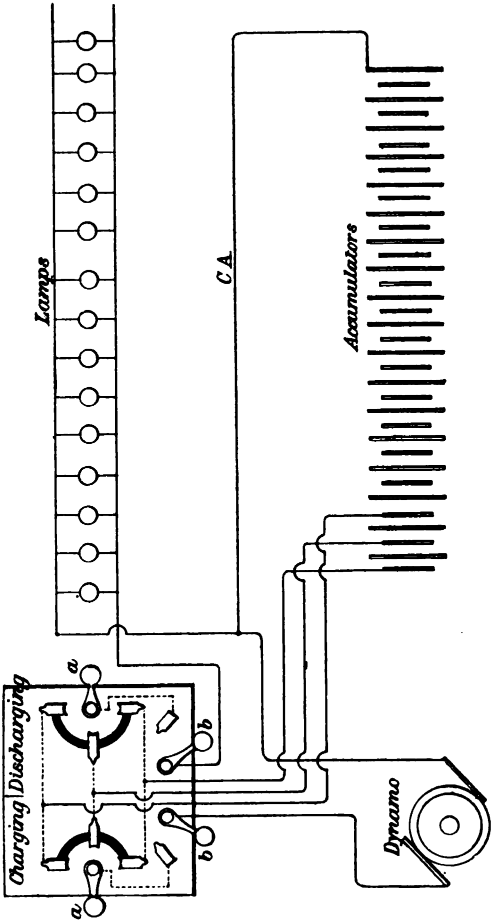


Fig. 86.—Diagram showing Manner of connecting Accumulators.

An ampèremeter should be included in the lamp circuit, to give notice of the rate of discharge, so that it may not exceed the maximum.

It is usual for the makers of accumulators to colour the terminals of the positive (+) plates red and those of the negative (—) plates black. The plates themselves are—positives, brown; negatives, grey. The positive and negative terminals above indicated are intended to be connected in charging with the positive and negative terminals of the dynamo. Care should be taken in putting the plates in their boxes, on setting up the battery. The negatives should be set to project equally on either side, in order that the positives may be firmly held by the rubber plugs or bands. The connections throughout the battery of 26 cells are, positive to next cell's negative, and so on throughout, leaving a free positive at one end and a free negative at the other.

The Electrolyte.—The dilute sulphuric acid must be prepared by pouring the acid into soft water, well mixed and allowed to cool (not the reverse), until the Twaddle hydrometer shows the figure 1·170. The acid should rather more than cover the plates, especially if the cell is not provided with a cover. It should not be put into the cells until the dynamo is ready to be switched on.

Before connecting the dynamo it is well to test it for polarity, in the manner usual in the case of accumulators working, as follows:—Place two strips of clean sheet lead in a stone jar filled with dilute acid. Separate them with a block of wood, and connect one to the positive terminal of the dynamo. Connect the other to one terminal of an incandescent lamp, and the other terminal of the lamp to the negative terminal of the dynamo. After the dynamo has been running for a few minutes the lead plate connected to the positive of the dynamo

should become brown, showing that the dynamo is giving current in the proper direction. This terminal is to be connected to the positive of the accumulator battery.

Charging.—The dynamo should run at full capacity, charging the cells until the liquid in the cells turns milky. On no account should the machine be stopped for at least 12 hours. The charging should be continued until the liquid is milky and the hydrometer shows the specific gravity to be 1·195. The specific gravity of the acid drops when first put in the cells, and it will not commence to rise for some time after charging has begun. The cells should be kept at all times as fully charged as possible, and never allowed to run down beyond three-fourths of the total capacity. Before stopping the dynamo, at all times, the accumulator must be switched off its circuit.

In charging, when nearly complete, the acid appears to boil; there is therefore a good deal of spray given off, which may be checked by glass plates placed above the cells, in the case of exposed glass boxes. While the accumulator is feeding the lamps the specific gravity of the solution will fall in direct proportion to the current drawn off. Thus, either the hydrometer may be used to test the above point, or the small accumulator voltmeter now supplied by makers to ascertain the amount taken out of the battery. It may be mentioned that as there is a good deal of hydrogen given off in charging, a naked light should not be taken near the cells if the space surrounding them be confined.

Sulphating.—This troublesome defect in the working is due mostly to bad treatment. It consists in a coating of white sulphate of lead, which forms on

the plates, choking their action. It may be obviated in a great degree by the following solution:—To a quart of strong solution of washing soda add 12 fluid ounces of sulphuric acid. This should be added to the cells in the proportion of 1 in 25. Sulphating is greatly caused by leaving the battery in a discharged condition. Cells that are badly sulphated, when one or two occur in a battery, will give a low E.M.F., and also show a low specific gravity. They may be brought into working condition again by *keeping them always charging;* thus by reversing their connections at every change of the main switch they will be continuously charged without interfering with the other cells, and in a short time the sulphate will break away, restoring the cell to full power. Cells should be tested occasionally, individually for voltage, specific gravity, and temperature.

Improved System of using Accumulators.—Messrs. Scott and Sisling have recently perfected a new system of working when accumulators and dynamos are intended to maintain the lighting in parallel to each other. They use a special kind of dynamo, which combines the advantages of a compound machine running at a constant speed with the convenience of accumulators for supply during light load and as an auxiliary to the dynamo. The special machine has two commutators, which are connected in series to give the voltage required for charging. The main commutator alone is concerned in supplying current direct to the lamps, the second commutator being brought into use for charging only. A special switch-board has two switches so interlocked that their manipulation is made quite simple, whilst the possibility of the compound dynamo

being reversed by the accumulators is prevented, although the dynamo and accumulators discharge in parallel to the lamps as in the ordinary arrangement with a shunt-wound dynamo. The current from dynamo to lamps never passes through any of the cells, so that no excessive current is sent through the regulating cells. All the accumulators, including the regulating cells, are charged during the hours of lighting, with a current which never exceeds the normal. The voltage is controlled by the engine governor, and does not depend upon the carefulness of the attendant. This saves labour and lamp renewals.

Description.—Fig. 87 (p. 259) shows the general arrangement. The dynamo armature has a main commutator, M, and an extra commutator, N. These two commutators are connected in series either directly or through the dynamo series winding, W. The switch-board contains two switches, viz., the dynamo-switch, D, which connects the dynamo to the lamps, and the accumulator switch, E, which connect the accumulators in either of three different ways, viz. A, to the lamps alone; B, to the lamps and dynamo; C, to the charging circuit. These switches are of the lever pattern and are interlocked by the thrust-rod, F. The handle, H, acts on the thrust-rod so that it can only put the dynamo switch "on." To take it "off" the accumulator switch must be moved so that the accumulators are connected to the lamps alone. When the dynamo switch is put "on" the thrust-rod moves the accumulator switch from A to B, thus connecting the accumulator to the dynamo in such a way that they are in readiness to assist in supplying current to the lamps without risk of reversing the dynamo. If the dynamo does not need

assistance, and spare power is available, the accumulator switch may be moved further from B to C, when the dynamo will charge the cells by means of its extra commutator, N, without interfering with the constant voltage which is supplied to the lamps from its main commutator, M. An index, I, shows whether the accumulators are being charged or discharged; whilst an ampèremeter, K, indicates the amount of the charging or discharging current. A second ampèremeter, L, shows the current taken by the lamps. A pilot lamp on the switch-board lights when the dynamo begins working.

Method of Working.—To start up, get the dynamo running at its normal speed. See that the pilot lamp on the switch-board is alight. Put the dynamo switch "on." The dynamo will then be supplying the lamps and the accumulators can be charged whenever spare power is available.

To Charge.—Move the accumulator switch to the gap between B and C. Put all the cells into circuit by the switch, R. Move the accumulator switch to C. The charging contact, C, is divided into sections, 1, 2, 3, 4, which are connected by three short coils of stout iron wire. These coils are securely mounted on insulators, attached to a cast-iron base, and are used to regulate the charging current when commencing to charge. After a short time the coils may, one by one, be cut out of circuit, and the charging current is then regulated by the switch, R. All the cells should be in circuit when starting to charge, so that the regulating cells may be switched out, one by one, after they are charged, and as soon as the charging current falls below that desired.

To Stop Charging.—Move the accumulator switch

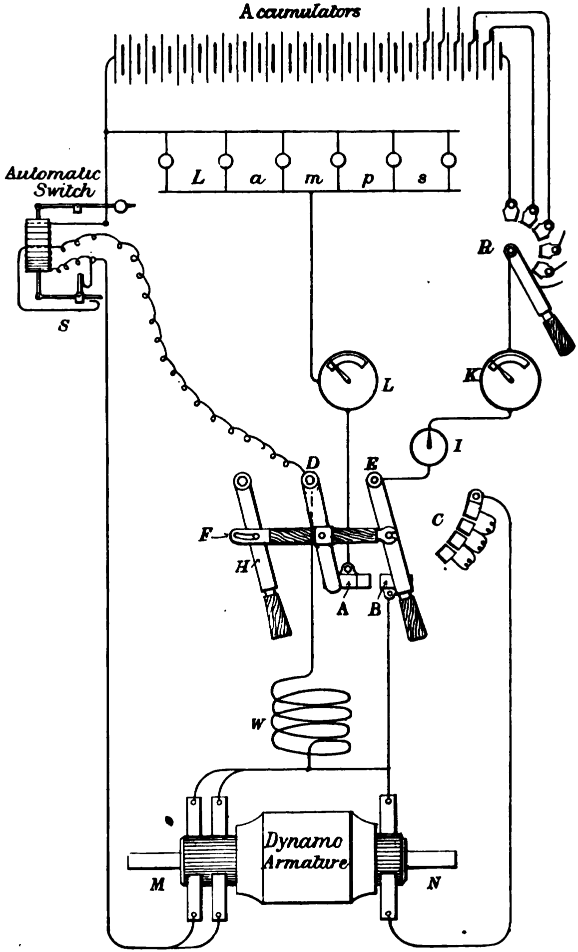


Fig. 87.—Diagram of Connections for Accumulators.

to the gap between B and C. Adjust the regulating

switch, R, so that the cells give the right voltage for the lamps. Move the accumulator switch to B.

To Stop Running.—Before slowing down, move the accumulator switch to A. This will connect the accumulators to the lamps and put the dynamo switch "off." The dynamo may then be stopped. An automatic switch, S, having shunt and series coils, will disconnect the dynamo when its speed slackens, and re-connect it when the proper speed is recovered.

CHAPTER X.

TYPICAL INSTALLATION.

PERHAPS there is no better instructor for everyday use than practice itself. In pursuance of this belief we consider that the most effective manner in which the present chapter can be made directly useful to practical men, is to furnish therein an exposition, in plain wording, of an actual installation. In some respects the installation we have chosen for treatment is a good typical example. But as it does not include accumulators it may be held to be imperfect in this respect. We would point out, however, that accumulators are confined more to pleasure yachts or small steamers, and that the average liner has no need for electrical storage.

Installation of the "Majestic."

(White Star Line.)

Number of Lights.—The total number of lights of 16 c.p. may be taken as equal to 1,200. This includes mast-head, side lights, compass or binnacle lights, telegraph lights, cargo lanterns and exterior deck lights.

Scope of the Electric Lighting.—While in ordinary steamers it is a common practice to use oil lamps for compasses, mast-head and side lights, and some-

times for minor purposes below decks, the lighting of the *Majestic* is entirely due to electricity. No difficulty has been experienced in adapting it to every purpose aboard the ship. This is the more remarkable in view of the predictions freely made some years ago, that electric lighting could only be used for the interior lighting, and was not adapted for compasses. The proof of the entire fitness of the incandescent lamp for any purpose aboard a large and fast steamer is complete when we consider that the vessel under consideration has crossed the Atlantic about twenty-four times every year since she was built, often in the worst weather ever experienced in that stormy sea, and that no fault has been found with the electric light. This is the more remarkable as the exterior lighting appliances of the deck houses are very much exposed to the weather.

Dynamos of the "Majestic."—These are of the Crompton horizontal type, and four in number. They are compound-wound. The four independent driving engines are of the Tangey compound horizontal type. They run at about 200 revolutions per minute. Below are given a few of the more important particulars relating to the dynamos :—

Elongated Gramme Armature.. ..	
Armature resistance	0.186 ohms.
Loss of E.M.F. in armature with 240 ampères	4·45 volts.
Resistance of the main magnet winding	0·0077 ohms.
Loss of E.M.F. in the main (series) magnet winding	1·86 volts.
Resistance of the shunt magnet winding	13·55 ohms.
Current in the shunt magnet winding	7·4 ampères.

Useful energy at terminals of machine	100 volts.	240 ampères.	24,000 watts.
Loss in armature			135 watts.
Loss in main magnet winding			445 watts.
Loss in shunt " "			740 watts.
			25,320 watts.

$$\frac{24{,}000}{25{,}320} = 94{\cdot}5\,\%$$

Temperature Tests :—

Temperature of engine-room	72 deg. F.
" armature after long test ..	101 "
" field magnet winding ..	92 "

Position of the Dynamo-Rooms.—These adjoin the engine-rooms, but occupy the third platform counting from the bottom. The port and starboard dynamo-rooms are quite distinct and independent, so that any accident to one would not interfere with the efficiency of the other. They are separated by a bulkhead, and the position chosen for the engines, being adjacent to the main engine-rooms, diminishes to a minimum the possible objection by passengers to the vibration of electrical machinery.

Switch-boards and Instruments.—There are two distinct sets of switch-boards, one set to each pair of dynamos. These may be worked independently or in concert. Several changes may be effected at the main and branch switch-boards : (1) All the circuits in the ship may be put upon any one dynamo ; (2) Any single circuit may be put upon one dynamo ; (3) All the circuits may be put upon two or more dynamos ; (4) The circuits may be divided into port and starboard and worked from port and starboard dynamos independently. The latter is the usual method of distribution. The instruments consist of two of Paterson and Cooper's ampèremeters and one voltmeter upon each main switch-board.

The ship is single-wired—that is, the return lead is represented by the shell of the ship, forming the usual "ship return." There are eleven active circuits and one reserve circuit.

The arrangement of the switch-boards, dynamos, and connections is represented in Fig. 88, where A and B show the main switch-board on the starboard side, and A′ and B′ that on the port side of the ship. These switch-boards are connected through the ampèremeters, *a*, to the respective starboard and port branch switch-boards, controlling the twelve circuits in the manner represented. The connections to the mains from the branch switch-boards lead off through two fuse boxes, indicated by 1, 2, 3, 4, 5 and 6 up to 12, and the number of lights upon each circuit or main branch is represented by the figures above. While the ampèremeters are always kept in circuit, the voltmeters, *v*, are provided with a switch by means of which they are kept out of the circuit except at the moment of taking an observation.

Ship Return Connections.—Each dynamo is furnished with a return connection to the shell of the ship as represented. The connection consists of a short length of cable, one end of which is attached to the negative (—) terminal of the dynamo, the other making connection with a gun-metal bracket bolted to one of the cross girders of the dynamo-room. Heavy main cables carry the current from the positive (+) terminals to the main switches, the connections being arranged as represented.

Work of the Dynamos.—There being 1,200 lights, and each dynamo being capable of running 400, it will be seen that there is always one dynamo in reserve, the whole of the lighting being maintained by

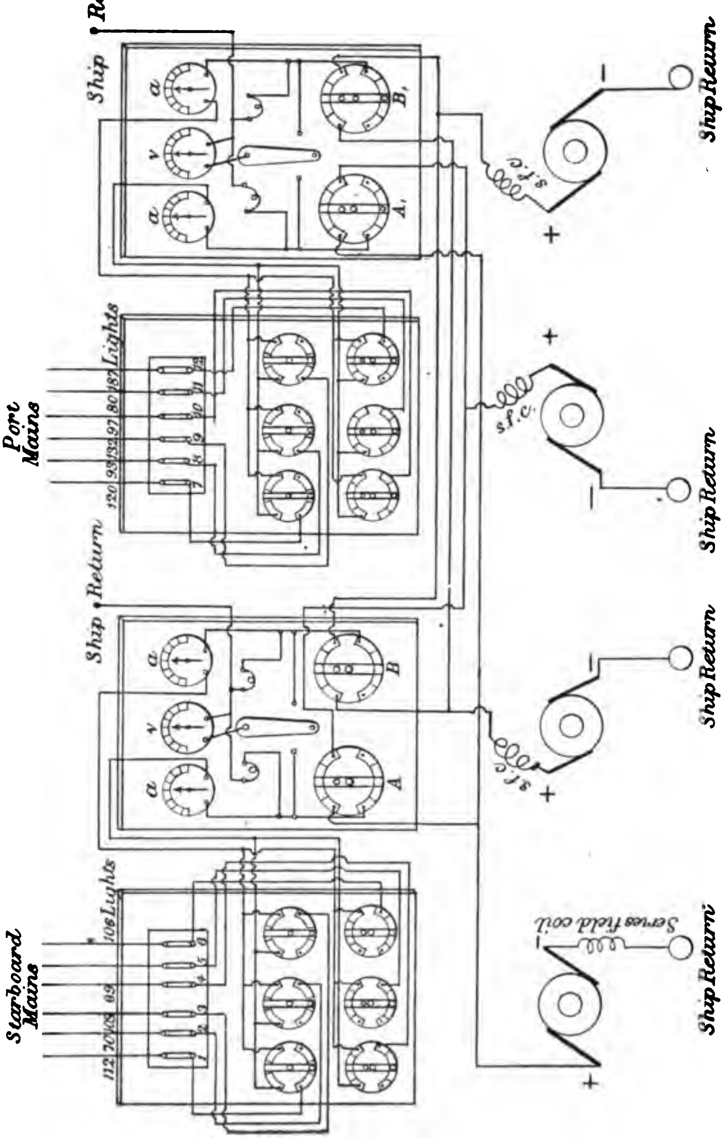


Fig. 88.—Circuit Arrangements of the Switch-boards of the "Majestic."

the other three. This arrangement not only provides against the risks of a break-down of any dynamo, but permits of the stopping of any machine for purposes of cooling, or attention to brushes or lubrication when necessary, the load of this dynamo being switched on to the reserve machine.

Distribution.—As before mentioned, the distribution is carried throughout the vessel by means of eleven circuits, each circuit again dividing into numerous branches. The scheme of dividing the lighting into two main sections, port and starboard, is again observed in the plan of the circuits. Thus, the starboard half of the main (1st class) saloon is fed from the starboard switchboard normally, but it may if desired be supplied from the port side. In like manner the whole of the more important departments, furnished with a considerable number of lights, are divided into two, and supplied independently. Hence, it is obvious that in the event of a break-down of the lighting of one side, there would still be sufficient current on the remaining side to fairly illuminate the space. These duplicate branches are carried to their respective areas by different routes, so that any cause of damage to the one may not affect the others.

Part of the scheme of distribution has already been given (page 160) as far as it affected the port side of the vessel. The destination and areas of the starboard circuits are tabulated on p. 267, where also are furnished the procedure usually followed in manipulating the switches. Most of the lighting is done by means of 16 c.p. lamps, with the exception of a few 50 c.p. lamps for special purposes.

The wiring is carried throughout in pitch-pine single groove casings, the wire being carefully puttied

STARBOARD.

Large Switch A controls Dynamos I. and III.

When circuits are to be run from dynamos I. and III. the sectional switch is to be closed over to A side.

ELECTRIC LIGHT INSTALLATION.

S.S. MAJESTIC.

No. III and IV. Starboard Dynamos. Main Contents on Sectional Switchboard.

NOTE.—At no time should any dynamo exceed 400 lamps at 100 volts=240 ampères.

STARBOARD.

Large Switch B controls Dynamos II. and IV.

When circuits are to be run from Dynamos II. and IV. the sectional switch is to be closed over to B side.

No. 1 Circuit, Main Deck.	Lamps.	No. 2 Circuit, Upper Deck.	Lamps.	No. 3 Circuit, Hurricane Deck.	Lamps.	No. 4 Circuit, Main Deck.	Lamps.	No. 5 Circuit.		No. 6 Circuit, Starboard Engine Room.	Lamps.
Starboard Half Saloon...	27	Upper whale back, & forward Emigrants' smoke room	22	Two cargo lanterns	20	2nd class smoke room	6			Tunnel	8
1st Class State Rooms and Stewardess' lavatory and bath	29	Upper deck state rooms forward, lettered I to T ...	22	Officers' quarters...	14	Port half 2nd class saloon	4			Lower platform ...	20
Starboard Half library	13	Upper deck state rooms, midship, lettered E, F, G, H, V, W, Y ...	9	Chart room, captain's room, starboard mast headlights, and telegraphs	19	2nd class pantry ...				Mid " ...	32
Saloon Dome ...	32	Passages on upper deck	14	Port half library ..	13	Passages and lavatory	9			Top " ...	4
Starboard half steerage & forecastle	6	Barber's shop ...	2	Upper deck promenade	12	Lights round steering gear	9			Sockets for portable lamps	3
Forecastle stores...	1	Bath room	1	Upper deck state rooms, A, B, C, D	6	Steerage lavatory, aft	14			Lavatory and engineer's stores ...	3
Socket for portable lamp	1			Passages leading to the above	4	Telegraphs, aft ...	11			Stoke-hole gauge-glass lights... ...	14
Starboard half of library lamp ...	3			Dome light over main stairway ...	4	Mid-deck & steerage, aft	11			Sockets for portable lamps in con. boxes	7
				Lights on stairway, aft saloon	6	Cargo lantern, aft...	11			Fan brass lights ...	8
				Lounge at end of library, port ...	3	Emigrants' galley...	3			Stoke-hole tunnel...	2
				Portable lamp in wheel house ...	2					Sockets for portable lamps over boilers	12
				Hurricane deck pantry	1					Fireman's stairway	3
				Forward, upper fans and stairways to boilers	5						
Total Lamps on No. 1 Circuit ...	112	Total Lamps on No. 2 Circuit ...	70	Total Lamps on No. 3 Circuit ...	190	Total Lamps on No. 4 Circuit ...	69			Total Lamps on No. 6 Circuit ...	106

into the channel. A cover of pitch-pine is afterwards secured upon the casing. The thickness of wood between the wire and the iron-work of the vessel is considerable, to insure against the intrusion of wet. The casings are well protected by coatings of white lead paint.

Binnacle or Compass Lights.—The compasses upon the bridge and aft are lighted by single 16 c.p. lamps of the usual pattern. The lamps are fed by a single or leading wire running up the column or pedestal of the instrument within a brass tube, the return being effected through the metal of the tube itself. The lamp is mounted upon an ordinary socket, in an upright position, within a square lamp box at the back of the compass case, as represented in Fig. 61, page 220. The compass lamps are turned on and off by means of switches within the wheel house. The more important wheel house or steering compass is lighted by a single 16 c.p. lamp suspended from the hood of the instrument. Its position is in the axis of the needle. It is fed by a twisted twin wire, brought down vertically as already described and illustrated at page 221. The standard Thomson compass is placed in an elevated position, above all the decks, and is not lighted.

Telegraph Lights.—The telegraphs, communicating with the engine-rooms and other parts of the vessel, are situated on the bridge. They are furnished with white glass dials and are lighted by transmission from a single lamp placed behind the dial, at a distance of several inches. The 16 c.p. lamp is placed in a brass rectangular box of sufficient size, and is fed by a single lead, as in the case of the compasses, running up through a brass tube behind the pedestal of each telegraph.

Side or Steaming Lights.—The red and green side lanterns are permanent fixtures to either end of the bridge. The front glass consists of an almost plane lens. The incandescent lamps are two in number, of 50 c.p. each, placed as close together as possible so as to insure the light occupying a central position. The lamps are upon separate switches, so arranged that one or both may be turned on as desired. The two lamps are only used in thick weather; at other times the reflection from the side lights, if too bright, is said to be unfavourable to good observation ahead from the bridge. The side lights are switched from the wheel house, situated beneath the bridge.

Mast-head Light.—This consists of a permanent lantern, with a thick, nearly plain clear glass front. The lamps are two in number, each of 50 c.p. The current is led up by means of a single lead run in a brass tube attached to the steel mast, and laid along the edge of the lap of the steel plate. The return circuit is effected through the metal of the mast itself.

Engine-Room and Stoke-Hole Lights.—All the wiring of these departments is carried through iron gas tubing for the sake of protection. This tubing is attached to the ironwork by means of strong saddles, and forms a sufficient protection against the roughest usage. A rather superior class of exterior insulation is employed in the case of the wires run in this way in iron pipes. The leads are merely drawn into the pipes, without additional surrounding material.

Cut-Outs.—In addition to the main cut-outs, there is situated a branch fuse at the commencement of every branch, and a single fuse at the root of the "twig" wire leading to every lamp. Fuses in the ceiling roses of lamps are not employed.

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Screw Steamer

Between *and* *Voyage*

189 Date.	Time.	No. of Lamps in use.	Revolutions per minute of No. 1 Engine.	Revolutions per minute of No. 2 Engine.	Hours run by No. 1 Dynamo.	Hours run by No. 2 Dynamo.	REMARKS.	Engine Oil. galls.	Tallow. lbs.	Waste lbs.	Number of Lamps renewed.	Other Stores.
	Midn. to 6 a.m.											
	6 a.m. to Noon.											
	Noon to 6 p.m.											
	6 p.m. to Midn.											
Totals ...							Day's Consumption					
Date.	Midn. to 6 a.m.											
	6 a.m. to Noon.											
	Noon to 6 p.m.											
	6 p.m. to Midn.											
Totals ...							Day's Consumption					

LAMPS.

On board...

Renewed......

Remaining...

Electrician.

Chief Engineer.

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